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ABSTRACT

A diversity of themes are addressed in the papers presented in this document; they include new topic areas as well as concerns that have been cited in previous issues. The papers focus on such topics as: (1) problem solving; (2) cognition; (3) the learning environment; (4) energy education; (5) the use of diagrams; (6) scientific methodology; (7) preservice teacher education; (8) misconceptions; (9) social background; (10) gender bias; (11) magnet schools; (12) teachers as researchers; (13) conceptual change; (14) teaching methods; (15) practical examinations; (16) non-formal education; (17) parental involvement; and (18) science curricula. A list of authors with addresses, and guidelines for authors are appended. (CW)

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Volume 17

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PREFACE

Research in Science Education has always contained a high proportion of articles reporting investigations in science education. Although there has been this bias to investigatory reports, there has also been a recognition of the complex relationships that occur between research and practice. The editorial committee believes that results reported in this journal have implications for practice and we hope that numerous readers have, as a consequence, altered science education practices. If that is the case the results have become more than just the stuff of journals and conference papers. This issue also presents more results from investigations and, once again, we hope that readers will act on the implications of the findings. The issue also differs a little from recent volumes of RISE in that there are several descriptive accounts of developments in science education. These accounts refer to changes in assessment practices, developments in science curricula and the nature of physics teaching in another cultural context. The editorial committee invites comments from readers about this greater mix of descriptive and investigatory papers.

Richard P. Tisher

Editor

Research In Science Education, 1987, 17, 1-10.

THE USE OF DATA IN PROBLEM SOLVING: THE WHYS, WHENS AND WHEREFORES

Chris Dawson and Jack Rowell

This study of students making inferences from provided data evolved from our investigations of the ability of individuals to control variables (Rowell & Dawson, 1984). In that work we used two types of problems; one requiring experimental design and one the interpretation of secondhand experimental data. This latter problem type was developed by Kuhn and Brannock (1977) who argued that design problems, such as used in Piagetian experimentation, lack a degree of validity because individuals are rarely required to design controlled experiments. Rather they are more likely to interpret data, which may not have been collected under controlled experimental conditions.

For example, consider the problem in Fig. 1. We, and Kuhn and Brannock before us, believed that a correct solution should identify the covariation of the level of only one variable with the outcome. From this a prediction can be made, and an explanation of it given. A full answer would indicate the limitations of the data, and the incompleteness of the interpretation which can be drawn.

Figure 1. The pendulum problem

I have been investigating some factors which may be related to the period of a pendulum (i.e. the time taken for a full swing). Three factors which have been studied are the length of the string, the weight of the bob (the piece of metal at the end), and the angle at which the pendulum is released. I recently looked at four experiments:

EXPERIMENT 1		EXPERIMENT 2	
length of string	25cm	length of string	100cm
weight of bob	50g	weight of bob	100g
angle of release	20^0	angle of release	20^0
PERIOD = 1 sec		PERIOD = 2 sec	

EXPERIMENT 3		EXPERIMENT 4	
length of string	25cm	length of string	100cm
weight of bob	100g	weight of bob	50g
angle of release	35^{0}	angle of release	35^{0}
PERIOD = 1 sec		PERIOD = 2 sec	

Question 1.

I have another pendulum set up under the following conditions:

length of string	25 cm
weight of bob	50 g
angle of release	35^{o}

a) What do you expect the period of this pendulum to be?

b) Explain your answer as fully as you can.

Question 2

a) Do you think that the weight of the bob has anything to do with the period?

b) Explain your answer as fully as you can.

But work with year 11 students has convinced us that those perceptions of the nature of the problem, and its demands, were too restricted. This can be seen by examination of some of the answers given, both to the problem in Fig. 1 and to two analogous problems (Fig. 2).

Figure 2. The rabbit and T.V. problems

Rabbit

Variables:	diameter of main artery	2mm or 4mm
	red blood cell count	$5x10^{9}$/ml or $8x10^{9}$/ml
	normal blood pressure (max.)	110mm or 140mm

Outcomes: tendency to have heart attacks, or not

Variable in question 2: normal blood pressure.

T.V.

Variables:	parents watch T.V.	a lot or little
	number of friends	few or many
	number of hobbies	few or many

Outcomes: students watch a lot of T.V., or little

Variable in question 2: number of hobbies

Typical student answers

Student explanations of answers given to questions 1 and 2 of each problem were classified into three basic kinds (a) totally data-driven; that is respondents based their answers solely on the provided data (b) non-data driven; explanations did not use the data at all (a few explanations used both data and non-data approaches), (c) avoidance of explicit explanation (includes 'don't know', no answer, guess, restatement of prediction, 'leads from data', etc.). Only the first two of these will be considered in detail.

Data-driven explanations

These were classified into two types. Type 1 used a covariation analysis either to identify the conjunction between the levels of one variable and the outcome (i.e. to infer a possible relationship), or to identify disjunction (i.e. that different levels of a variable are associated with similar outcomes, and thus that the two are not related), or both. Some examples are:

> "In two of the previous explanations when the string has been a length of 25cm it has a period of 1 sec."

> "Because in different groups they have different weights and the period is the same."

Type 2 answers used data in a variety of ways not related to covariation. Generally the item for which a prediction was to be made was compared directly with data in one or more of the four experiments. Some examples are:

> "As in experiment 1 the string length is 25cm, weight of bob is 50g and in experiment 3 the angle was 35 degrees. All of these numbers are found in the question on this page."

> "The extra 15 degrees would only take 1/2 sec as in experiment 1. The only difference is the angle of the release."

> "It's striking a medium between 1 and 3, and 2 and 4."

Non data-driven explanations

These appeared to use none of the data provided. Rather, explanatory frameworks for the prediction (whether right or wrong) were constructed either from general knowledge or belief about the situation described (type 3), or from more specific knowledge (type 4). Some examples are:

> Type 3. "The diameter of the main artery probably would not be wide enough and would be a strain on the rabbit's heart."

> "Students have not many hobbies or friends so to fill up their spare time they watch T.V., and because their parents don't watch T.V. the set is always free."

> "Socially parents have failed. They have very few interests and hobbies hence the child sees this, knows they watch only a little T.V. and try to become more interested in life. T.V. is a means of this."

> Type 4. "Because it has a greater gravitational attraction, being heavier coming down and momentum keeps it faster on the way up."

> "There is no reason for weight to affect the result as all acceleration due to gravity is equal and it is unlikely that any of the blobs (sic) would reach terminal velocity."

Combination of explanations

A very small minority of students examined their prediction from two points of view - both data and knowledge of the situation were used independently, almost always in support of each other.

Explanation type and problem content

To investigate any relationship between the type of explanation and the problem content, almost all year 11 students (N=155) in one coeducational, independent school took a test, with each giving answers to three problems - T.V., Rabbit, and Pendulum (Figs. 1 and 2). Student explanations were classified as types 1, 2, 3, 4 or Avoidance, and are reported in Table 1.

Clearly there was a different balance between data and non data explanations in the three problems. Non data answers were considerably more common for the socially orientated T.V. problem, whereas data driven explanations were more common for the other two. However in those two the relative numbers of type 1 and type 2 explanations differed, with the rabbit problem showing a preponderance of type 1 explanations and this being reversed in the pendulum problem.

Table 1. Categorisation of responses of year 11 students to questions 1 and 2 on three problems. (Answers to question 2 in brackets)

Problem Content	Data-Driven Type 1	Type 2	Non Data-Driven Type 3	Type 4	Avoidance
T.V.	16 (12)	1 (1)	136(127)	-	2 (15)
Rabbit	63 (53)	19 (3)	54 (62)	-	19 (37)
Pendulum	31 (22)	72 (3)	12 (29)	2 (31)	40 (70)

DISCUSSION

What we hadn't considered, prior to using these problems, is the possibility of reaching a satisfactory solution (to the problem solver) without any reference to the data (i.e. type 3 and 4 answers). Explanations can be shaped to make good sense, both rational and coherent, from only an idiosyncratic knowledge base. In this strategy the provided data has no relevance; and it appeared to be treated in that way by many respondents.

Ultimately empirical studies need a theoretical model which can unify and explain them. In this case a model must recognise, and account for, the diversity of the answers observed, and their relationship to the context of each problem. Several possible models exist: one, which integrates Piagetian theory with those of the cognitive psychologists, and is both structural and functional, develops the notion of access to various schematic representations (Rowell & Dawson, 1987). Another potentially fruitful functionalist approach has been developed by Evans (1984) from an analysis of respondents' solutions to questions generally framed in more classic, logically structured formats.

Evans sees human reasoning, of all types, as involving a two stage process. Firstly pre-attentive heuristic processes (note that his usage of 'heuristic' differs from that of other in its emphasis on rapid and non-conscious processing), to an extent in response to linguistic and semantic cues in the problem statement, select both from all the novel information, and from the individual's existing knowledge and belief, what is perceived as being relevant to problem solution. Secondly analytic processes, if they are engaged, construct a solution from that selection: at its best this is logically derived from the 'relevant' information.

If this theoretical approach is to provide useful interpretations of the above results, and if the two hypothesised stages are relatively independent, then it should be possible to examine some of the characteristics of each by adapting the presentation of problems in different ways. The remainder of the paper look at some preliminary work designed to undertake this examination.

Examination of the heuristic processes

It follows from the above discussion that if similarly structured problems are framed in different content areas, then because the general knowledge-base of the group of problem solver differs (in addition to idiosyncratic differences), heuristic processing should select different aspects as relevant for further analytic processing. Some evidence for this is seen in Table 1 where data-driven answers were much more commonly observed in some contexts than in others; in addition the way in which the data was used varied from context to context.

Two experiments were undertaken focussing on characteristics of heuristic processing. In the first a prompt was inserted into each problem, with the intention of suggesting to students the importance of data to scientists. It was anticipated that this could influence the heuristic processing, resulting in a greater proportion of data driven answers. In the second, respondents were asked to predict, before receiving each problem statement, whether or not they would expect each of the three variables to be related to the outcome. Our belief here was that this constraint to commit themselves could strenthen students' reliance on non-data answers, possibly as a result of the rationalisation (analytic) or belief biases (heuristic) they made evident. Both of these approaches were conducted with a single class of students, using half the class as a control group, but neither intervention had any effect on the relative numbers of the different types of explanations given. We intend to investigate further to what extent the heuristic stage can be deliberately modified by prompts and instructions.

Examination of analytic processes

The concept of a distinction between heuristic and anlaytic processing is attractive at first sight, but may be difficult to support empirically. Clearly the function of analytic processing must be the use the 'relevant' information to shape a coherent explanation which relates the variables, and their levels, to a predicted outcome. Two experiments were undertaken to examine the explanatory frameworks generated when slightly different forms of the same problem were answered. The first was 'science' oriented (the fertiliser/chemical problem), and was set in two alternate forms, one for each half of a year 11 physics class (N=26). The basic structure of the problem was identical to that in Fig. 1 and discussed the growth of a group of plants with the following variables: amount of water administered weekly 50ml or 100ml, amount of daily light 6 hr or 12 hr, amount of fertiliser (or chemical) applied weekly 1g or nil. The prediction part of the problem asked for the growth state under the following conditions: Test A: amount of fertiliser = 1g, amount of water = 50ml, amount of sunlight = 12 hr. Test B differed from Test A only in that 'chemical' was substituted for 'fertiliser'. In both a covariation analysis predicted poor growth.

Our belief was that the connotations of 'chemical' might be suggestive to students of a neutral, or slightly negative, effect on plant growth, whereas 'fertiliser' might be expected to stimulate growth. It was also believed that any such difference might be reflected in the explanations given. The results are reported in Table 2.

Table 2. Classification of student explanations to question 1 of the fertiliser/chemical problem.

	Data answers		Non Data answers
	Type 1	Type 2	
Test A (N=13) (fertiliser)	7	5	1
Test B (N=13) (chemical)	12	1	-

All 13 students answering the 'chemical' problem offered data explanations, with 12/13 of these being type 1 answers following a correct prediction. However only 8/13 students correctly predicted the answer to the 'fertiliser' problem with 7 of those giving type 1 answers. Some type 2 responses typical of this group were:

> "It grows well. It has same light and water as experiment 4."

> "In the other examples with 50ml and 12hr the plants grow well. The addition of fertiliser should enhance the growth of plants."

Because these results were obtained from only a small group of students the degree of their reproducibility is not yet known. However there is evidence that the variable 'fertiliser' is processed rather differently to 'chemical', though the reason for this difference is not clear. In the 'chemical' problem the covariation analysis made by most students suggests that all the provided data was selected as relevant in the heuristic step and then used during analytic processing. However those students adopting a type 2 answer in the 'fertiliser' problem referred to only part of the data in their explanations. It is not clear whether this difference resulted from different heuristic processing which identified some data as irrelevant, or from different analytic processing which, as a result of prior 'knowledge', shaped the explanation in a rather different way. Whatever the case the difference, if replicable, must be related to differential prior 'knowledge' of fertiliser and chemical, as anticipated.

A second experiment, which looked at two forms of a problem set in a social context where it was correctly anticipated that, like the T.V. problem (Table 1), an increased number of non data explanations would be given, will not be reported in detail. It is sufficient to say that in this situation also the results demonstrated a processing difference consequent on a small difference in wording. But whether that difference related to heuristic or analytic aspects of processing we were unable to tell. Further experimentation, including a 'thinking aloud' approach, is planned to further investigate these differences.

SUMMARY AND DISCUSSION

There is evidence from these experiments that Evans' model of problem solving might be of further use in the exploration of the processes involved in solving this type of problem, though it is still not clear whether the separate outcomes of heuristic and analytic processing can always be distinguished in practice.

In general terms we have shown that analogous questions, set in different contexts, tend to be tackled quite differently. Generally, data seems to be more commonly used when the situation can be seen to be 'scientific' in nature (rabbit and pendulum), and is less likely to be used in non-scientific (social) situations, a difference also reported by Gladstone (1984). However the degree of prior understanding of the situation (or even of specific knowledge) must also be considered in addition to the science/non-science context. As the breadth of general background knowledge of students is likely to be greater in the social problems used than in the scientific ones, it is most probable that for this reason also respondents will be more able to construct a non data-driven explanatory framework. Where the immediate content is less familiar, a data based approach may be more readily generated.

In addition where some limited, and possibly specific knowledge exists, there is evidence that data will be used but the strategy will reflect aspects of the specificity (our type 2). For instance many students appeared to have some familiarity with the pendulum and the effect of the three variables, and some of these ideas were seen in non data explanations; but the data answers also reflected a tendency to use limited prior knowledge to make direct comparisons of the unknown with individual experiments. For instance, a relatively common approach in the pendulum question (20/72 type 2 answers in Table 1) was to state categorically that one variable cannot have any effect (often this was weight); this allowed a simple direct comparison to be made with data in just one of the four sets provided.

There is obviously much more work to be done on these, and similar problems, to investigate the relationships between the putative heuristic and analytic processing, and the problem content. Some of the studies presented above require replication, and there are other aspects which require further examination.

IMPLICATIONS

One factor which is of importance to us as teachers is how we could help students recognise when data is important in finding the best solution to a problem. Generally we muddle through life without using first hand, or even second hand, data to help us. Most of the time this is a successful, and by far the most economical approach. At other times, and we see this with political and environmental problems, the need for data to be used with other knowledge is vital if a rational decision is to be reached: too often opinion, without data, is made to go a long way.

At this stage the best generalisable approach we can suggest is to work with students on a range of problems, from the trivial to the socially and scientifically important. Teacher and students could look at each problem, and expecially at what data would be needed if they were to attempt to produce a 'best' answer. They would then consider the overall importance, either to an individual or to society in general, of obtaining a 'best' answer, and balance this against the effort of obtaining and analysing the required data. In other words what really is needed is a STOP AND THINK step between the heuristic and analytic steps. In a narrow sense, isn't this part of the scientific approach to problem solving. And, in a broader sense, isn't it part of being rational?

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LEARNING IN SCIENCE: SOME WIDER PERSPECTIVES

Jan Garrard

INTRODUCTION

When White and Tisher reviewed the past ten years of research in science education for the Third Handbook of Research on Teaching they noted the emergence of several major new themes in science education research over the preceding ten years (White, 1983).

One of the dominant of these new themes has been that of the learner as an active meaning-maker, both in the 'real world' of everyday life experiences and in the world of new science learning in the classroom. Interest in the interface between existing everyday beliefs and new science learning has led to extensive research aimed at describing students' existing beliefs, and exploring the ways in which new learning interacts with these prior understandings. Through the use of naturalistic/qualitative rather than experimental/quantitative methodologies many empirical data, theoretical models, and practical applications have emerged from these studies over the past ten years.

This research is now at a reflective stage: in historical terms ("Where have we been?"), in philosophical terms ("What are we doing?"), and in terms of future directions ("Where are we going?") (White, 1983; Gunstone et al., 1986).

However, thus far this reflection has tended to be within the boundaries of science education research itself. In this paper I also wish to be reflective, but in the wider context of creating some links between research into children's understanding of science and some other relevant areas of research.

The three themes that will be discussed are as follows:

(i) The notion of 'children's science' versus 'scientists' science' will be compared with exemplary versus formal theories of concept, and with natural versus formal modes of reasoning.

(ii) A proposal will be presented for a way in which process and content may be related in the meaningful learning of science concepts and theories.

(iii) The student-as-scientist metaphor is questioned. I propose that much learning in science can be viewed as a phenomenological investigation of the socially constructed world of scientific knowledge rather than as a scientific investigation of the natural world.

A note on terminology

The science education research referred to in this paper has been variously labelled "misconceptions", "alternative frameworks", "conceptual frameworks", and "children's science". It is my view that a more appropriate term is that of "implicit science". This term has been borrowed from an equivalent term in social psychology (Wegner and Vallacher, 1977) where "implicit psychology" refers to the psychological theories people develop in order to explain aspects of their psychological and social world. Thus, "implicit psychology" represents a constructivist view of the way in which people make sense of their social and psychologicial reality, in the same way that "implicit science" represents a constructivist view of the way individuals make sense of their physical reality.

These theories are common-sense theories - they are assumed rather than examined and are therefore implicit rather than explicit.

I believe the term "implicit science" is an excellent label for this area of research in science education: it is not judgemental; it does not imply that only children hold these views; it stresses the unexamined nature of the beliefs; and it relates this important and growing area of science education research to an equivalent and more established area of research in social psychology.

DISCUSSION

'Children's science' and 'scientists' science': learning as substitution or learning as the acquisition of co-existent systems of beliefs?

A recurring theme within implicit science research has been that of the interaction between scientists' and teachers' understanding of science concepts and theories, and students' alternative conceptions. A question commonly asked is: "What can be done to change alternative conceptions?" (e.g. Gunstone et al., 1986).

Current research into concept understanding within cognitive psychology may lead to a questioning of the notion of replacing students' conceptions with scientists' conceptions. This research, which will be described briefly below, suggests that dual concept meanings (i.e. 'everyday' meanings and 'scientific' meanings) may be both acceptable and functional.

As an example of differing concept definitions consider the following definitions of the concept of 'drug' taken from a recent study by Garrard (1987). Students were asked: "What do you mean by the word 'drug'?" Compare the following definitions:

(i) *Heroin**. (year 11 student)

(ii) Like *cocaine** – it will kill your brain cells. (year 7 student)

(iii) Smoking *marijuana**. (year 10 student)
(*my emphases)

(iv) Any chemical entity or mixture of entities, other than those required for the maintenance of normal health, the administration of which alters biological functions and possibly structure. (WHO, 1981)

Definitions (i) to (iii) are examples of 'prototypical' or 'exemplary' definitions of a concept (in this case 'drug'), while the last definition (i.e. (iv)) is an example of a 'classical' or 'formal' definition (Gleitman et al., 1983). The formal theory of concept representation (sometimes called the 'definitional' theory of concept) suggests that when individuals use a concept such as drug they think in very general terms about the necessary and sufficient features which *define* that particular concept. On the other hand, a prototypical theory of concept suggests that an image of some sort of typical exemplar of the concept is formed. Thus, in the prototypical perspective, in comprehending, reasoning with, or communicating about a particular concept we utilise a functional example or an exemplary member of the category to stand for the concept.

According to the 'formal' or 'definitional' theory of concept, individuals' mental representations of the concept of 'drug' would include heroin, cocaine, coffee, and beer with equal status, since all of these substances alter biological functions. However, according to the prototypical theory of concept representation, the word "drug" effectively *means* our mental representation of what we consider to be the 'druggiest' drugs (in the study by Garrard (1987), nearly always drugs such as crack, heroin, or cocaine rather than coffee, beer or analgesics).

In cognitive psychology research, evidence for concepts as prototypical categories comes from two types of studies: reaction time studies and exemplariness ratings studies. In exemplariness ratings studies, subjects are asked to rate exemplars of a superordinate category on a scale according to how good an instance of its category each exemplar is considered to be. Many such studies have found a high degree of consistency among subjects (and between studies) in that, for example, apples are considered to be very good exemplars of fruit while olives and figs are considered to be less 'fruity' fruits (Gleitman et al., 1983).

However, not all concepts are of the everyday type such as 'fruit' and 'vegetable'. In an exploration of a possible distinction between everyday concepts such as 'fruit' and 'vegetable' and the more classical, definitional, all-or-none concepts, Armstrong et al. (1983) measured exemplar ratings and reaction times for supposedly well-defined categories such as 'even number', 'odd number', and 'female'. Thus, in the exemplar rating task, subjects were asked to distinguish among the odd numbers for oddity. Common sense would suggest that one cannot do so, but the subjects could and did, and, furthermore, raised no objections to the task. Similarly, in the reaction time task, subjects were asked to verify, as quickly as possible, the truth of statements such as "Nine is an odd number". It was found that exemplariness ratings and differential reaction times for verification showed similar patterns for well-defined mathematical concepts as for the everyday concepts.

In a further attempt to explore whether people acquire and organise definitional and prototypical concepts differently, Armstrong et al. (1983) asked a new population of subjects to tell them straight out whether membership in the category was graded or all-or-none for a variety of definitional and prototypical concepts. It was found that all subjects stated that membership of the mathematical concepts was all-or-none, with about half of the subjects claiming that membership in the everyday categories was also all-or-none. The same subjects who had said that it was absurd to say that some odd numbers were odder and some fruits fruitier were then asked to rate exemplars of these categories on the usual seven-point scale. These subjects were again able to provide the exemplariness ratings, although they seemed to show some equivocation by using less of the rating scale than did the original subjects.

Several explanations for these findings have been proposed. One explanation is that, psychologically speaking, odd numbers as well as fruits and vegetables are represented mentally by family resemblance structures. In other words, even concepts which can be explicitly defined are, nevertheless, represented prototypically.

An alternative explanation is the dualistic theory of concept which holds that individuals can represent the same concept differently, and that the elicitation of a particular response depends on what question is asked of the subject. In other words, an individual has access to both a prototypical and a definitional concept of, say, 'odd number', and the elicitation of one or the other form of the concept is context dependent.

Gleitman et al. (1983) illustrate this distinction as follows:

> For example, suppose you want to find a grandmother in Yankee Stadium. It pays to have a workable representation of likely grandmother candidates for these rough identification purposes. You ought to look around for a grey-haired lady with a

> twinkle in her eye, preferably one dispensing brownies. This is faster than making genealogical inquiries. But to reason about the concept 'grandmother' (e.g., to decide whether somebody's grandmother might be a virgin), you had better refer to a representation that stipulates that grandmothers are mothers of parents."

Thus, prototypical classification is a useful heuristic for many of the problems of everyday life. It is no surprise that it is so widely used in such a variety of contexts - it works. However, there are occasions when a logical classification is called for. Although Neimark (1983) concludes that the prototypical classification system is a 'defective heuristic approach to classification', that it is a 'default processing system', I suggest that questions of the relative importance, or power, or superiority of one system over the other are questions of value rather than empirical questions.

Debate over the existence and relative value of prototypical versus definitional structure of concept mirrors an equivalent situation in the area of cognitive processing where 'plausible', 'practical', or 'reference point' reasoning has been contrasted with 'formal' reasoning which is seen as correct and logical, but abstract and of little value for most purposes apart from intellectual gymnastics by scholars trained in formal logic.

Basically, the argument is that logical reasoning is not our usual - or natural - mode of reasoning. In addition, the technically invalid kinds of reasoning people generally employ are frequently very effective, not only in everyday life situations but also in areas requiring a highly sophisticated level of expertise where it might be supposed that rigorous deductive thinking is essential (Johnson-Laird, 1984; Rosch, 1983; Hunt, 1982).

As in the previous discussion of the prototypical/definitional structure of concepts, a dualistic approach to reasoning processes appears to be appropriate. Thus, individuals possess both logical and natural reasoning skills and the elicitation of one particular strategy in preference to the other is dependent on contextual variables. We can reason logically when we are asked to or when the task requires it and the rest of the time we reason plausibly.

Contemporary science education needs to address the question of the relative value of prototypical concepts and natural reasoning (children's science?) compared with definitional concepts and logical reasoning (scientists' science?). As long as the former were considered to be inherently 'wrong' or at least inferior to the latter, the replacement of 'children's science' by 'scientists' science' could be seen to be a worthwhile educational objective. Increasing recognition of the functional value of prototypical concepts, natural reasoning (and children's science?), should lead to an evaluation of this position. This is a particularly relevant question within the 'science for all' philosophy of science education. Definitional concepts, logical reasoning, and scientists' science are certainly functional for professional scientists and engineers and for science teachers (although, as discussed earlier, not their only mode of functioning). However, are they always functional for the general population who need a working knowledge of science and technology and how it affects them personally, and the society they live in?

In addition, science education research which assesses students' 'scientific' beliefs by asking them to discuss and reason about everyday life situations needs to be aware of the possible contextual dependence of students' responses. Inferring a lack of scientific knowledge when the task might seem to the student to require everyday knowledge and natural reasoning could underestimate the student's dually held scientific knowledge. The holding of dual systems of belief might seem inherently wrong or logically contradictory to the science educator who spends most of his or her time functioning in the 'scientific mode'. However, such a dual system could be functional for the non-scientist whose everyday life situations often require quick, practical (but not always 100 per cent correct) decisions, frequently in the face of scientific theories which are counter-intuitive and therefore seemingly ineffectual in practical life.

A possible relationship between content and process in meaningful learning

What is it that develops when cognition develops? A set of general cognitive operations, or bodies of discipline-specific concepts? Science educators such as Karplus (1977) draw on Piagetian theory and argue for the importance of general cognitive operations. On the other hand, science educators such as Novak (1985) draw on Ausubel's theory of meaningful verbal learning and argue the importance of acquiring content specific knowledge. Other science educators argue that both aspects of cognition are important (Lawson, 1982) but they tend to see content and process learning as complementary but separable aspects of learning. In this paper I will argue that content and process are inextricably connected in the acquisition of knowledge.

Content knowledge is frequently seen in terms of knowledge of specific concepts. These concepts are then said to be linked together in cognitive structure in various hierarchical (Novak, 1977) or other more asymmetrical arrangements (Collins and Loftus, 1975). Meaningful learning then becomes a process of concept acquisition together with concept linking. In the terminology of West et al. (1982), students acquire an understanding of the "nodes" themselves (which in the West et al. (1982) terminology include concepts and propositions), and also an understanding of how the nodes are interconnected.

The notion that meaningful learning involves meaningful linking or relating of concepts as well as an understanding of some sort of conceptual "core" of the concept itself is well-established in constructivist science learning, with theorists such as Ausubel (1968) and Osborne and Wittrock (1985) stressing the importance of relating new concept learning to existing understandings. However, these theorists have not explicated the actual nature of these links or relationships. In addition, research designed to explore these relationships has been largely unsuccessful. For example, in a study of the cognitive structure of undergraduate chemistry students as they learnt new concepts in chemistry, Fensham et al. (1981) found that students had some difficulty articulating the nature of those relationships; that is, the links between concepts.

It appears that while we know a lot about concept acquisition (the conceptual "cores" or propositional "nodes" in cognitive structure), we know little about what many researchers and theorists believe to be the essense of understanding - the relationships between these concepts or nodes. However, some researchers seem to have a 'feeling' for what these links might be like. These 'feelings' have been expressed in terms of examples that illustrate the links; and metaphors that point to the links. Thus, Osborne and Wittrock (1985) discuss the processes of "linking", "contructing", and "subsuming" in their theory of generative learning. Osborne and Wittrock go on to illustrate these three processes using examples from physics (Osborne and Wittrock, 1985) and biology (Osborne and Wittrock, 1983). However, they do not attempt to explicate the actual processes of "linking" and "constructing meanings" in any detail.

Similarly, West (1984) alludes to a 'vine' metaphor of learning to explain the relationships between concepts in cognitive structure, and Pines (1981, 1985) uses a 'woven fabric' metaphor to illustrate the nature of conceptual relationships. However, examples of linked concepts, and metaphors for the linking process do not explain the actual nature of the linking.

Pines (1985) comes closest to an explication of meaningful linking when he identifies two types of concept relationships: set-element relationships (i.e. set-subset); and whole-part relationships (i.e. system-element). Pines goes on to state that this rudimentary analysis represents a first step towards a taxonomy of relationships in content and cognitive structures:

> I have attempted ... to provide an analysis of meaning demonstrating that relations underlie all meaning. I wish to subsume all meaning under this single category (relationship) with the hope that it will provide a new avenue for fruitful educational investigation and practice. Providing a taxonomy of conceptual relations, if it can be achieved, will, I predict, have profound ramifications for research in cognition, developmental psychology, and epistemology. (Pines, 1985, p.115)

However Pines seems to be unaware that a partial taxonomy of relationships already exists in the form of Piaget's cognitive operations.

As an example, consider the learning of the concept of 'isotope'. Those who focus on the learning of specific content suggest that the meaningful learning of 'isotope' would depend on connecting isotope to the concepts of protons and neutrons. But the relationship between protons and neutrons that gives 'isotope' its meaning is that of relative number (i.e. operational knowledge). Further, if we attempt to anchor 'isotope' more meaningfully by presenting examples (e.g. Carbon-11, Carbon-12, Carbon-13), the examples only aid meaningful meaning if the student has the relational (i.e. operational) knowledge of class inclusion; that is, knows what it means for something to be an example of a superordinate class.

This explanation of concept links as operational relationships explains the great difficulty students have in articulating the connections they have made between specific concepts. As Anderson (1980) points out, one of the distinctions between content knowledge and process knowledge is that the former can be readily verbally communicated while the latter cannot be so easily communicated verbally.

Recognition of the role of process knowledge in scientific laws which can be expressed mathematically is well-recognised. However, I go further than this by suggesting that perhaps all scientific concepts, propositions, and theories derive much of their meaning from the mental operations that link them. Thus, content knowledge in science depends on process knowledge. At the same time process knowledge is content dependent: mental operations are always operations on something.

Thus, content and process knowledge appear to be more interconnected than has been previously recognised. In particular, I have argued that process knowledge may be a useful way of understanding the links or relationships between concepts in cognitive structure.

Another aspect of implicit science research in recent years that has been influential in shaping our understanding of learning in science has been the concept of the 'student-as-scientist'. In the following section I argue that a more appropriate metaphor for learning may be the 'student-as-social-scientist'.

The 'student-as-social-scientist': learning as a phenomenological investigation of the socially constructed world of scientific knowledge

The constructivist view of learning is basic to all implicit science research. But what is constructed, and from where? One view has been that the student behaves like a scientist in re-discovering for himself or herself the laws of science through processes analogous to those of the original scientist; that is, through direct observation of and direct experimentation with the natural world.

Thus, discovery learning was seen as a process of knowledge acquisition which modelled both naturalistic concept acquisition in everyday life (through 'bottom up' learning processes such as those described by Piaget (1964), Bruner (1966), and Gagne (1965)), and scientific knowledge acquisition (through the various processes of scientific investigation as described for example by Hodson (1985)).

However, knowledge acquisition can also occur through a process of 'top-down' concept learning as described by Ausubel (1968), Novak (1977), and West and Pines (1984).

This is the more formal 'school' learning process which Ausubel (1968) claims can be just as effective as (and more efficient than) learning based on naturalistic 'bottom-up' concept formation.

It is this process of 'top-down' school learning that I would like to relate to some aspects of social science research in the same way that discovery learning, or the student-as-scientist metaphor has been compared with the process of natural science research. Methods used by social scientists to explore the social world are frequently different from those of natural scientists. In particular, the so-called 'naturalistic enquiry' paradigm (Lincoln and Guba, 1985) arguably has provided more valuable research methodologies for exploring social reality than has positivistic science. The socially constructed world of scientific knowledge is a part of social reality rather than physical reality. Therefore it might be more useful to think of learning in science as the exploration by the student of this social reality rather than of physical reality. And further, this exploration could be seen as profitably employing a naturalistic enquiry methodology rather than an experimental 'scientific' method.

One of the naturalistic enquiry methodologies that might prove valuble in undertstanding the learning process is that of phenomenology. Phenomenology has been described by Karl Jaspers as:

> The completest and most careful description possible of what is experienced by ... people. (Misiak and Sexton, 1966, p. 414)

The phenomenal data that have been explored by psychologists include perceptions, feelings, images, ideas, etc. - anything that appears in consciousness. Through the three phases of phenomenological intuiting, analysing, and describing, the phenomenological psychologist explores the meaning that stimuli, situations, or understandings have for the individual (Misiak and Sexton, 1966).

A fundamental aspect of the phenomenological method involves the researcher freeing himself or herself from any preconceptions or presuppositions about the phenomena that are being explored. This suspension of judgement while one looks in an unbiased way at 'what is there' has become a basic tenet of naturalistic enquiry, particularly as it has come to be applied within implicit science research. Thus, the science education researcher as phenomenologist uses open-ended, non-cuing stimuli, tasks, and questions to elicit and describe students' understanding of the natural world.

What I am proposing is a reversal of this situation. Thus, in the process of learning, the student becomes a phenomenological investigator of the socially constructed world of science knowledge. The student's task becomes that of exploring scientists' and teachers' understanding of the natural world. This view of learning contrasts with many aspects of the discovery learning or 'student-as-scientist' view of learning. However, in common with discovery learning or the student-as-scientist view of learning, it is also a constructivist view of learning: the difference lies in *what* is constructed (the immutable 'laws of science', or scientists' current interpretation of reality), and *how* it is constructed (through experimentation and observation by the student of the natural world, or through the student phenomenologically exploring the world of scientists' and teachers' understanding of the natural world).

This view of learning in science is consistent with the notion of dual understandings of science concepts discussed earlier in this paper. If learning in science is seen as the acquisition of an understanding of scientists' interpretation of the world rather than an understanding of reality *per se* then the notion of dual concept understandings becomes less problematic: everyday beliefs and scientific beliefs become alternative conceptions with their own usefulness and limitations.

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IMPROVING THE LEARNING ENVIRONMENT FOR ABORIGINAL STUDENTS IN SCIENCE CLASSROOMS

Steve M. Ritchie

INTRODUCTION

Much of the literature related to Aboriginal education (e.g. Davis et al., 1980; Ganambarr, 1982; Harris, J., 1978; Harris, S., 1984; Hastie & Treagust, 1985; Makin, 1977) is concerned with the development and implementation of programs and/or teaching strategies. Davis et al. (1980), for example, describe a community-based science program which was planned around the seasonal variations at Milingimbi, Northern Territory. They emphasize the need for teachers to involve students in activities requiring observations of context-specific events (e.g. classification of "shellfish" on the mud flats). Some other recommended teaching practices for use in Aboriginal schools include: establish personal rapport with students, ensure that ongoing tasks are mastered before new concepts are introduced, and encourage cooperative learning (e.g. Makin, 1977).

Since the majority of Aboriginal students are educated in urban and rural schools, it is ironic that most research into Aboriginal education has been conducted in Aboriginal community schools (e.g. Milingimbi). In Queensland, for example, only 1/6 of the Aboriginal school students attend community schools (Young, 1987). Therefore, there is a need for studies related to the efficacy of science programs and teaching strategies for Aboriginal students in urban and rural schools. The study reported in this paper is concerned with an evaluation of one (rural) school-based science program developed in an attempt to improve the learning environment of its participants - many of whom were Aboriginal. Before discussing the purpose, method and results of the study, the program is briefly described.

PROGRAM DESCRIPTION

The program was designed to provide alternative science instruction for poor readers in normal classes. However, many of the poor readers were also Aboriginal. Therefore, the program was developed to accommodate the differences in cultural backgrounds and preferred learning styles between Aboriginal and non-Aboriginal students identified in the literature (e.g. Harris, S., 1984).

Although the program has been described previously (Ritchie, 1985a), the number of improvements made to the program as a result of small-scale evaluations undertaken since (e.g. Ritchie, 1985b), warrant a brief updated description. Therefore, the program is outlined as it was implemented in its last year of operation.

Up to eight poor readers from each Year 8 class were placed in groups (pairs) by their teacher to encourage cooperative learning. Each group worked as a separate unit through a set of mastery learning modules written by Stuart Traynor (1980). These modules were written specifically for poor readers of less than average ability and required students to undertake a variety of concrete activities. Audio-tapes of these modules were provided and adult tutors (teacher aides) were allocated to each lesson to assist the poor readers.

The teacher typically initiated each lesson for the good readers who were not selected to participate in the program whilst the poor readers worked independently from the class - obtaining assistance from each other, the tutor and less frequently, the teacher. Although the teacher often introduced concepts in class by selecting a few activities from Traynor's (1980) modules, the good readers participated in a different set of learning experiences than the poor readers. However, the program for poor readers was designed such that there was some degree of compatibility between the concepts covered by the poor readers and those which were exposed to the good readers in class.

PURPOSE

The following questions provided a focus for this investigation:

1. How do the learning environment perceptions of Aboriginal and non-Aboriginal program participants compare?
2. How do the learning environment perceptions of Aboriginal program participants and non-participating Aboriginal students compare?

3. Do the learning environment perceptions of Aboriginal program participants improve over the course of the program?

METHOD

Student perceptions of the program were obtained from the analyses of responses to learning environment perceptual measures. further insight into the implementation of the program was obtained by interviewing program participants (students and staff) and observing a number of lessons.

Sample

The program was implemented in three of the four Year 8 classes at the study school. Twelve of the 16 students who participated in the program were Aboriginal.

Design

Two instruments, namely, the My Class Inventory (Fraser et al., 1982) and the Individualized Classroom Environment Questionnaire (Fraser, 1986a) were administered before the implementation of the program and again, about six months later. The My Class Inventory (MCI) was well suited to students with reading difficulties since it was primarily developed for use in upper primary classrooms. This instrument consists of 38 items, with each designed to fit one of five scales (six for Cohesiveness, eight for Friction, eight for Difficulty , nine for Satisfaction, and seven for Competitiveness).

Since the students involved in this study were older and more mature than primary students for whom the MCI was designed, the MCI administered differed from the original form in that the two-point response format was replaced by a four-point response format (Stongly Disagree, Disagree, Agree, Strongly Agree) to provide a greater range of responses. Scores of 4, 3, 2 and 1 were allocated to responses of SA, A, D and SD, respectively, except for reversed items where the scores were similarly reversed. Neutral responses (errors or incomplete items) were given a score of 2.5.

The learning environment dimensions assessed by the MCI, however, neglected the System Maintenance and System Change Dimensions Category, considered one of the three categories essential for psychosocial environment assessment (Moos, 1974). Similarly, there were some aspects of science classroom environments (e.g. participation in a number of varied investigations) not assessed by the MCI. The Individualized Classroom Environment Questionnaire (ICEQ) was used to address these neglected areas.

The ICEQ differs from other classroom environment instruments in that it assesses those dimensions (e.g. Participation, Investigation) which distinguish individualized classrooms from conventional ones. The ICEQ contains 50 items altogether, with an equal number of items belonging to each of the five scales (viz. Personalization, Participation, Investigation, Independence, Differentiation). Each item is responded to on a five-point scale with the alternatives of Very Often, Often, Sometimes, Seldom, and Almost Never.

Data Analyses

The validity and reliability of the MCI and ICEQ instruments have been demonstrated in a variety of classrooms throughout the world (e.g. Fraser, 1986b). Acceptable reliability estimates for the scales of these instruments were also obtained for the population (N=89) of Year 8 students at the study school. For example, the calculated Cronbach alpha reliability coefficients for some of the scales were: Cohesiveness = 0.80, Friction = 0.83, Satisfaction = 0.81, Personalization = 0.68 and Investigation = 0.70.

Analysis of Variance (ANOVA) was used to investigate differences in the means obtained by the groups of Aboriginal and non-Aboriginal program participants, and the groups of Aboriginal program participants and non-participating Aboriginal students. In addition, the t-test was used to determine the levels of significance of differences between pre- and post-test scores on each of the learning environment scales for the sample of Aboriginal program participants.

RESULTS

Table 1 shows the mean scores for the classroom learning environment perceptions on nine scales from the MCI and ICEQ instruments held by Aboriginal and non-Aboriginal program participants. Only the ICEQ scale of Independence was not considered because the program participants did not work by themselves but rather in pairs, and therefore, it seemed an inappropriate scale.

The Aboriginal program participants perceived their learning environment more favourably than did the non-Aboriginal participants on the MCI scales of Cohesiveness (17.33 v 14.00), Friction (17.25 v 22.25), Satisfaction (26.33 v 25.25) and Competitiveness (17.50 v 18.75). Of these, only the difference for the scale of Friction ($F = 7.04$, $p < 0.05$) was statistically significant. In contrast, the Aboriginal participants perceived their learning environment less favourably than did the non-Aboriginal participants on all of the ICEQ scales used. Of these, the scales of Participation ($F = 9.97$, $p < 0.01$) and Investigation ($F = 6.02$, $p < 0.05$) revealed statistically significant differences.

TABLE 1
Mean scores for the learning environment perceptions
held by Aboriginal program participants and non-Aboriginal program
participants on nine scales from the MCI and ICEQ

Scale	Aboriginal Student Mean (N = 12)	Non-Aboriginal Student Mean (N = 4)	
Cohesiveness	17.33	14.00	
Friction	17.25	22.25	*
Difficulty	18.25	18.25	
Satisfaction	26.33	25.25	
Competitiveness	17.50	18.75	
Personalization	34.50	36.00	
Participation	30.42	36.50	**
Investigation	30.75	36.00	*
Differentiation	27.58	32.50	

Degrees of freedom on numerator = 1
Degrees of freedom on denominator = 14
* $p < 0.05$
** $p < 0.01$

The difference on the MCI scale of Friction can be explained by noting that some of the non-Aboriginal students who had been assigned to the same work-groups (pairs) proved to be incompatible. The differences on the ICEQ scales can be explained by the data collected during the lesson observations. (A total of 20 lessons were observed during a six month period). Aboriginal students tended to initiate discussion with the tutor and undertake laboratory activities less frequently than did the non-Aboriginal students. This was particularly noticeable in groups where an Aboriginal student worked with a non-Aboriginal student. In these groups, the non-Aboriginal student tended to adopt a leadership role.

Even though only small sample sizes were possible for this investigation, the data relating to perceptual differences between Aboriginal and non-Aboriginal participants were strengthened by the lesson observation data. Therefore, concern for developing programs which aim to provide variations in learning environments for Aboriginal students is well founded.

Not all of the Year 8 Aboriginal students at the study school participated in the program. Five Aboriginal students were considered by their teachers to be reasonably good readers and were not selected to participate in the program. Table 2 shows the mean scores for the learning environment perceptions held by Aboriginal program participants (N=12) and those Aboriginal students who did not participate in the program (N=5). On all but two scales (Participation and Investigation), the Aboriginal participants perceived their environment more favourably than the non-participating Aboriginal students. However, only the scale of Satisfaction (F=13.49, $p < 0.01$) revealed a statistically significant difference. Therefore, it would be reasonable to conclude that Aboriginal students should find participation in the program more satisfying than conventional studies.

TABLE 2
Mean scores for the learning environment perceptions held
by Aboriginal program participants and non-participating
Aboriginal students on nine scales from the MCI and ICEQ.

Scale	Mean for Aboriginal Program Participants (N=12)	Mean for Non-Participating Aboriginal Students (N=5)	
Cohesiveness	17.33	14.80	
Friction	17.25	20.60	
Difficulty	18.25	20.60	
Satisfaction	26.33	21.60	**
Competitiveness	17.50	18.60	
Personalization	34.50	31.80	
Participation	30.42	31.80	
Investigation	30.75	31.40	
Differentiation	27.58	27.40	

Degrees of freedom on numerator = 1
Degrees of freedom on denominator = 15
** $p < 0.01$

TABLE 3
Pre-test and post-test scores on nine learning environment
scales for Aboriginal program participants
(N = 11)

Scale	Pre-test Mean	Post-test Mean	
Cohesiveness	16.64	17.18	
Friction	17.45	17.36	
Difficulty	20.09	18.09	
Satisfaction	23.27	26.45	**
Competitiveness	17.09	17.45	
Personalization	33.55	34.45	
Participation	30.55	30.45	
Investigation	28.09	30.36	
Differentiation	25.55	27.45	

Degrees of freedom = 10
** $p < 0.01$

Eleven Aboriginal participants were available during both pre- and post- program administration of the MCI and ICEQ instruments. Table 3 shows that improvements were recorded for the scales of Cohesiveness, Difficulty, Satisfaction, Personalization, Investigation and Differentiation. Of these, only the scale of Satisfaction ($t = 2.82$, $p < 0.01$) revealed a statistically significant improvement. Because the number of program participants who completed both pre- and post-tests was small, the statistical power of this result was somewhat limited. Nevertheless, this result was strenghtened by the supportive statements made by participants during their interviews. Examples of student and staff comments included:

> It's fun ... because you do experiments. (Student)
>
> ... most people have really enjoyed their time in that group. I think one of the main advantages would be to maintain interest ... they develop skills in an interesting way. (Teacher)

CONCLUSIONS AND DISCUSSION

The implementation of the program at the study school significantly improved the level of perceived satisfaction amongst the Aboriginal program participants. In addition, the Aboriginal program participants perceived their environment (as measured by the scale of Satisfaction) more fabourably than the Aboriginal students who did not participate in the program.

Although only small sample sizes were used in this study, it is likely that the strategies used in the program (e.g. concrete activities, mastery learning, cooperative learning) would have wider appeal. An additional technique which could be used to improve the learning environment for Aboriginal students in science classes is to prepare curriculum materials which focus on Aboriginal science. In other words, science courses could be based on appropriate aspects of Aboriginal culture and lifestyle (e.g. technology of fishing traps, foods of ritual significance, flight of boomerangs).

Young (1987) refers to the process of including the study of Aboriginal science in school curricula as "Australianization". If teachers and curriculum developers accept the challenge of "Australianizing" science courses in urban and rural schools, it is not only possible that all students will learn to appreciate the diversity of practices and lifestyles of the original Australians (Scott, 1986), but also Aboriginal students might feel that the subject is more worthy of their active involvement (Young, 1987).

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THE MATTER OF ENERGY

Malcolm Carr, Valda Kirkwood and Barry Newman

INTRODUCTION: PROBLEMS

The Learning in Science Project (Energy), undertaken by the Science Education Research Unit of the University of Waikato - Hamilton Teachers College, New Zealand, has made us painfully aware of an issue which teachers constantly face: how a specific concept is to be understood. In this project, it was the concept of energy, understandably, which claimed our attention, a concept of no little significance for science curricula.

It was cause for concern to recognise that there are a considerable number of difficulties associated with the understanding of this concept. Some of these are of a philosophical kind while others are educational in nature. Problems of one kind frequently entail problems of the other.

ORIGINS OF SOME PHILOSOPHICAL AND EDUCATIONAL PROBLEMS

Concepts Evolve

A term such as 'energy' evolves over time. Elkana (1974) argues for the tortuous development of an understanding of the term in a physics context in the nineteenth century and Cohen (1974) maintains that such an understanding, in the same context, has undergone significant revision in the twentieth.

In Different Contexts Concepts Evolve Differently

Such a term also evolves in different contexts differently. Phrases such as 'energy budget' and 'profiles of energy distribution' in a biology context are far removed from the 'potential energy' and 'kinetic energy' ideas of classical physics. A science, technology and society or a chemical engineering context is likely to nurture its own special brand of energy, while different languages, and different cultures using the same language, will presumably make their distinctive contribution to its characterisation.

For One Person Or Context There May Be Differences

Distinctions such as 'technical vocabulary' and 'folk definitions' (Laferriere, 1987) or other labels like 'layperson's usage', 'science teacher's usage' and 'scientist's usage', helpful as they are, still do not do justice to the situation. For instance, such terms fail to indicate that an individual may be inconsistent in usage and that there may be differences of usage among those operating in the same field.

Science Teachers With Different Background May Teach Differently

Kirkwood et al. (1986) have suggested that science teachers with differing academic backgrounds may teach about energy in different ways. A teacher with a tertiary physics education might have a perspective on energy related to, capacity to do work, conservation of energy, heat, mass-energy relationships, quantum mechanics and fields. Biological perspectives might reflect ideas on energy related to, energy sources, energy flow through biological systems, energy balance and energy rich and energy poor compounds.

One can understand if the specialist biology teacher tends to colour his teaching with energy flow diagrams and traces systems back to the sun. One can similarly appreciate the physics teacher seeing 'capacity to do work' in all her carefully designed practical activities and teaching accordingly.

How Does This Affect The Students?

What happens to students, meeting at different stages of their junior science educational experience a variety of teachers with their different perspectives? Does an inability to come to terms with the concept as taught by the teachers save them from distress or do they exhibit considerable creative ingenuity in making sense out of the potentially perplexing? Do they learn to play different games for different contexts, particularly perhaps, as they progress to science at the senior level?

Students Already Have A Point Of View

It is now well known (e.g. Brook and Driver, 1986; Carr et al., 1987) that students come to the classroom with their own thoughts on the subject. Teaching that fails to take into account students' perceptions, their use and understanding of language, and the ways in which they are likely to respond to teacher offerings, is setting a course for educational mishap. One would be unwise to dismiss ideas such as 'the world's running out of energy', 'fat people must have lots of energy but they don't seem to' or 'cars create energy when they move' as of no consequence when trying to introduce the subject of energy in a scientific context. Likewise, having concluded a unit on energy, responses from students such as 'the light energy was stored in the battery', 'look at all that nuclear energy - the sound, light and heat' or 'the elastic energy gets smaller because the spring gets smaller' should cause teachers to try again.

SOME PHILOSOPHICAL PROBLEMS

Given science education's interest in the scientific domain, we will restrict our discussion under this heading to this area and ignore references to energy in popular discourse.

The 'Discovery' Of The Concept Of Energy

Elkan's account of the 'discovery' of the conservation of energy principle is a sobering one and appropriate for setting the stage for our discussion. He maintains that "the general concept of energy became meaningful only through the establishment of the principle of conservation of energy in all its generality" (p. 9), "the concept of energy as we know it today ... has emerged from Helmholtz's 1847 paper 'Uber die Erhaltung der Kraft' and that up till then, nobody, including Helmholtz himself, had a clearly defined concept of energy" (p. 9) and " the very ambiguity in the word 'Kraft' (The German word 'Kraft' is usually translated into 'force' or 'strength') is indispensable for the comprehensibility of" Helmholtz's paper (p. 17).

What Does 'Conservation Of Energy' And 'Energy' Mean?

The intricacies surrounding the development of the concept and the lack of clarity concerning what was to be understood by 'Kraft' (Helmholtz substituted 'Energie' for 'Kraft' some years later, see Elkana, p.133) should warn us to tread carefully even today in our efforts to proclaim what we mean by the term. Keeton (1940), almost a century after Helmholtz's paper writes: "the theory of the conservation of energy as matter of fact, is extremely ambiguous".

Cohen (1974) in his Foreword to Elkan's work states that the conservation of energy principle is now known to be false. He makes this claim apparently because of his views on energy/matter (mass?) relationships, which probably entail that mass is gained or lost at the expense or otherwise of energy. Gauld (1984) argues that such a position is based on misunderstandings of both energy and mass.

The Experts Don't Agree

Certainly the experts differ. Warren (1983) maintains that "energy is an advanced abstract concept, the capacity to do work". On the other hand, Kemp (1984) argues that the notion that energy is the capacity of a body for doing work is "misleading if not completely incorrect". Concepts are of course what we make of them and we may argue for the acceptability of such notions on grounds relating to, for example, increased understanding, greater consistency or better communicability. Schmid (1982), accordingly, argues that energy can be understood as a primary underived physical quantity and refers to a course based on this understanding. It is a course which involves "part of a restructuring of physics as a whole" - a sober reminder that no prescription for a scientific concept is a sacrosanct.

What About Other Experts?

Furthermore, what are biologists or chemists, to make of these pronouncements in physics? Are the physicists the only one entitled to say what energy is? Van Koevering *et al.* (1987) write with ease of 'flow of energy', 'energy efficiency', and 'the conversion of solar energy to corn and alcohol', all a far cry from 'capacity to do work', or 'internal energy'. Though questions of the economical, productive and consistent use of the term may always be relevant, by what criteria could we argue that biologists, as opposed to physicists, should not develop their own conceptual networks?

The Creation Of the Energy Concept

Simply put, the energy concept, considered in whatever domain, is a creation and different creators have been at work and continue to be at work with different results. Given that all concepts are creations however, a more helpful position might be to consider the question of the sense in which the energy concept relates to reality, give a reality.

In What Sense Does Energy Exist?

Energy may be thought by some as existing in the way that chairs are thought to exist. Perhaps for others it is considered to exist as love exists. For yet others it may be thought of as a creation brought about to unify a variety of phenomena. Whatever our own position, one can understand there being some objections to the idea that energy exists as a moo cow exists. One could argue that energy, in a scientific context, only came into 'existence' a little over a hundred years, when its concept was created, whereas moo cows have been around much longer than that. Conversely, it may be argued that moo cows are easier to see but that for some time humanity has been groping about in the darkness with a vague idea of energy in mind and only in recent times has light dawned.

Regardless of our difficulties in handling the notion of existence however, it is another problem that energy ideas are often raised in contexts which seem to suggest no questions about their existence or creation. Both teacher and student alike often seem to be quite ignorant of historical processes and the part played by minds and the relevance of both for our understanding of the type of entity that energy is or might be.

PHILOSOPHICAL QUESTIONS OF DETAIL

Contexts For Asking Philosophical Questions About Energy

When one raises philosophical questions one does so with particular contexts and perspectives in mind. For example, from a biologist's point of view, the notions of energy being stored in biochemical systems and being transferred from one system to another are likely to be seen as appropriate, whereas references to the notion of capacity to do work are likely to be regarded as quite inappropriate. Even within specific disciplines, different contexts may demand different perspectives.

Some Questions About Energy

Not forgetting the problem of which perspective one wants to adopt and when, the following issues are a small sample of the myriad which can be raised.

* What is the relationship between energy and work? (Of course, this and other questions can be rephrased in terms of what we would prefer rather than in terms of "what is").
* What is the relationship between heat transfer and internal energies?
* In what sense is energy a condition rather than a process?
* Should one make a distinction between mechanical energy and internal energy?
* Why do we hold to the principle of conservation of energy?
* What constitutes a form of energy?
* What connections are there between one form of energy 'decreasing' and another form 'increasing' in the same system?
* Are such connections causal and what might we mean by causal?
* What do we understand by energy degradation and how are the ideas of useable or useful energy associated with it?
* In what ways do the terms 'potential' or 'stored' assist or serve to cloud our understanding of the concept 'energy'?
* What is meant by an energy source and in what sense does energy flow?
* How does one define the boundaries of one's system and what's the value of doing this?
* What do we understand by fields, energy stored in fields, equipotential line, field strengths and field lines?

Such questions serve to give us some idea of the character of the monster that resides within our scientific and educational house.

A Few Ideas

A few comments on such issues:

(i) There could be some value in helping students to recognise energy forms as phenomena with which we associate energy, rather than types of energy.

(ii) If students are to be introduced to potential and kinetic energy types, it might be of some value to indicate their similarities and differences. Both types are analysed with reference points in mind, but one type is associated with movement while the other is not, though changes in the other will involve movement.

(iii) It might be helpful to associate changes in kinetic energy with changes in 'quantity' (the sound died away, the car accelerated), whereas changes in potential energy could be associated with changes in 'appearance' (the nuclear or chemical materials have altered, the magnets are closer together).

(iv) It might also be helpful to realise that while it may be easy to recognise that kinetic energy has increased or decreased, it may be very difficult if not impossible, at first glance to appreciate whether potential energy has changed at all. One may need to know the conventions that apply to various situations or one may need to have access to certain otherwise obscure empirical data and even then, only an appeal to conservation of energy may help.

(v) There is something odd about an entity which can 'exist' as being two types, kinetic and potential (internal energies being reduced to these), being conserved. Being of two types is suggestive of the entity having too much flexibility for conservation to apply. The flexibility is lost however, if one type inexorably follows the other as night follows the day. The extent to which the two can be tied together depends upon one's creativity and choice of models when analysing phenomena such as collisons or light emissions. Are these ideas helpful educationally?

CONCLUSION: SO WHAT'S THE MATTER?

Is 'energy' the worst of those concepts with which we have both educational and philosophical concerns? Who knows? Regardless, our sympathy to those involved in associated research and a warning to tread cautiously in other areas. 'Energy' today, 'space', 'time' and 'matter' tomorrow.

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TEACHING THINKING - A FOCUS FOR SCIENCE TEACHING?

John Edwards

INTRODUCTION

For almost ten years now papers presented to the Australian Science Education Research Association have been detailing the weakness of current school science prgrams for developing good scientific thinkers. Papers such as Gunstone and White (1980) and Brumby (1982) show that even the best products from secondary school science programs are sadly deficient. This problem is not confined to science education or to Australia. Nickerson et al. (1985) summarise the U.S. experience:

> "It is an indisputable fact that many students do not acquire the ability to think very efficiently as a consequence of their educational experience, and, until recently, relatively little attention had been given to the possibility of making the teaching of thinking skills a primary educational objective, in the sense in which the teaching of reading, writing, and mathematics are primary educational objectives." (p.6)

It is the second of these issues that is addressed by this paper. What happens when the teaching of thinking skills becomes a focus in the classroom? And what place should the teaching of thinking skills have in the science classroom.

BACKGROUND

In 1977, as Head of the Science Department in an Australian male independent school, I was faced with the problem of very able senior science students showing a disturbing lack of ability to apply their scienctific knowledge in even moderately novel situations. This was in spite of their high ability levels and the successful completion of four years of what appeared to be a very thorough and well-taught junior secondary science program.

Following a review of available programs it was decided to introduce de Bono's CoRT-1 program (de Bono, 1981) as a one-month segment in the grade 10 science program. The effects on students and teachers were fast and positive. Anecdotal evidence was overwhelmingly positive, and while the design of the associated action research study was weak the results were encouraging (Edwards and Baldauf, 1983). Students showed large increases in the number of ideas, quality and structure of answer to a familiar essay topic, and in the novelty and number of ideas generated on an unfamiliar essay topic. There was also a strong correlation between performance on the CoRT materials and on the end-of-year science exam, even when the effect of student I.Q. was controlled.

The classroom success of the CoRT-1 program in increasing confidence and flexibility of student thinking, particularly in novel or unfamiliar situations, led to a desire to more closely identify the effects of the CoRT-1 program on students, teachers and classrooms. A series of research studies has resulted, two of which will be reported here.

THE CoRT-1 MATERIALS

The CoRT-1 program (de Bono, 1981) is a set of ten lessons each presented on a separate sheet. A brief overview of each sheet is given in Figure 1. There are five other CoRT packages, each also containing ten lessons. CoRT-1 aims to broaden student perception by demonstrating a number of different directions that thinking can follow. Students are encouraged to use specific thinking tools to develop the habit of broadening their thinking.

Working through each CoRT-1 sheet takes about 45 minutes. So, in total, the CoRT-1 program covers about eight hours of instruction. Students work from individual copies of the sheets. First the particular thinking skill is described and explained by the teacher using an example. Then the students apply the skill to two or three practice items, working in groups of three or four. A brief whole-class feedback and discussion session is held after each practice item. After this there is a whole-class discussion of the use of the thinking skill and the principles that apply to it. Usually students also do a short homework project to apply the skill.

FIGURE 1

CoRT-1 Thinking Lessons: A brief Overview

Adapted from the CoRT-1 Teachers Notes

Sheet 1:	PMI (plus, minus, interest). This involves looking for the plus points (P), the minus points (M), and the interesting points (I) in any idea. The aim is to enlarge one's view of a situation and to provide a means of by-passing the natural emotional reaction to an idea.
Sheet 2:	CAF (consider all factors). This involves the exploration of a situation before coming up with an idea. The aim is to attempt to be as complete as possible in considering all the factors in any situation.
Sheet 3:	RULES - this provides an opportunity to practice PMI and CAF. PMI is used on an existing or proposed rule. CAF is used when making a rule.
Sheet 4:	C & S (consequence and sequel). This deals with what may happen after a decision is made. Immediate, short term (one to five years), medium term (five to twenty-five years) and long term (over twenty-five years) consequences are systematically explored.
Sheet 5:	AGO (aims, goals and objectives). This introduces and emphasizes the idea of purpose. Both aspects - "because" and "in order to" - are investigated.
Sheet 6:	PLANNING - this provides an opportunity to practice C & S and AGO, and to a lesser extent PMI and CAF.
Sheet 7:	FIP (first important priorities). This is a focusing device, directing attention to what is important. This is only done after using the earlier skills to generate as many ideas as possible.
Sheet 8:	APC (alternatives, possibilities and choices). This encourages the student to generate possibilities beyond the obvious and satisfactory ones. It is used as an antidote to emotional reaction or rigid thinking.
Sheet 9:	DECISION - this provides an opportunity to practice FIP and APC and, in a general way, the earlier skills.
Sheet 10:	OPV (other point of view). This directs attention to other people's point of view. It is used to balance the focus in the earlier sheets on one's own point of view. The possible differences between viewpoints are emphasized.

THE STUDIES AND THEIR FINDINGS

Both studies to be reported here were done with intact grade seven classes in rural Queensland primary schools.

In the first study (Edward and Baldauf, 1987, in press) sixty-seven students in three classes completed the CoRT-1 program in four weeks. Students were pre-tested with a range of instruments and fifteen weeks later (eleven weeks post-treatment) the same instruments were used as delayed post-tests. There was strong anecdotal evidence, from interviews with students and parent questionnaires, of the percieved value of CoRT-1. The harder data revealed statistically significant improvements in I.Q., creativity (flexibility and originality) and self concept as a learner.

The second study (Edwards and Baldauf, 1987) involved two hundred and two students in two schools. Two classes in each school formed the treatment group of 115 students, two classes in one school and one in the other formed a control group of 87 students. The CoRT-1 treatment took five weeks and students were pre-tested, post-tested and given a delayed post-test four weeks later.

The first study had shown that both the Otis-Lennon School Ability Test - Intermediate Form R (Otis and Lennon, 1982) and the Torrance Test of Creative Thinking - Verbal Test Booklets A & B (Torrance and Ball, 1984) were reliable measures and so these were used again. The Self Concept as a Leaner Scale (Waetjen, 1967) was shown to be an unsuitable instrument for this population (Baldauf, Edwards and Matthew, 1985) and for the second study it was replaced by a specially developed instrument: the Self Concept as the Thinker Scale.

Once again there was a statistically significant increase in I.Q. and in originality, for the treatment group compared to the control group. The trends in results from the Torrance Tests were the same in both studies: large increases in fluency of thinking, larger increases in flexibility of thinking, and largest increases in originality of thinking. There was no increase in self concept as a thinker in the second study. However, interesting results emerged from an analysis of the performance of the students on their normal mid-year and end-of-year examinations. There was a statistically significant overall improvement in academic achievement for the treatment students compared to the control students. In particular subject areas: there were very large gains in language arts, gains in social science, but no shift in mathematics or science.

GENERAL IMPLICATIONS

For many, the strong anecdotal support for the CoRT-1 program from teachers, students and parents in the series of studies reported here would be sufficient to warrant its inclusion in the curriculum. However, harder data are the normal prerequisite for curriculum change. Nickerson, Perkins and Smith (1985) and Polson and Jeffries (1985), in reviewing the teaching of thinking skills, point to the very uncertain nature of the methodology and instrumentation for measuring the effects of such programs. As de Bono (1976, p.200) puts it:

"... testing think is extraordinarily difficult and be set with pitfalls."

The results from the three studies reported here are encouraging, particularly when one considers that these results have come from a treatment of approximately eight hours. At the same time it is clear that much more research needs to be done to develop improved methodologies and instrumentation in this rapidly expanding area.

There already exist a very wide range of programs designed to develop thinking skills and each has an enthusiastic following among educators, particularly in the U.S. These programs, and attempts to evaluate their effects on students, are well described in Costa (1985) and Segal, Chipman and Glaser (1985). The clear message from both of these sources is the enormous educational potential in shifting from the current approach of teaching thinking as a by-product of the teaching of academic disciplines, to the direct focussed teaching of thinking skills. Mann (1979) has reviewed the history of such approaches from the days of Socrates and Plato. Many of the issues which have arisen through time are still with us today. The major debate at present centres on the importance of domain-specific knowledge. While researchers such as Greeno (1980) and Polson and Jeffries (1985) give such knowledge a central focus, other such as Simon (1980) and de Bono (1976) favour the learning of generalisable skills which can then be applied to a range of areas:

> "The evidence from close examination of AI (artificial intelligence) programs that perform professional-level tasks, and the psychological evidence from human transfer experiments, indicate both that powerful general methods do exist and that they can be taught in such a way that they can be used in new domains where they are relevant." (Simon, 1980 p.86)

Significant improvements in students' thinking skills from relatively short treatments, as reported here, are typical of the findings from research in this area. Large issues remain to be investigated: How generalisable are the thinking skills? What are the longer term effects on students? and, What are the effects of more substantial treatments? The next study in the series reported here, which is currently in progress, involves teaching a group of grade seven students the full CoRT program, of approximately 50 hours, over one year with deliberate transfer to the discipline areas built in.

The regular cry for a "back to basics" has been with educators throughout our lifetime. A new voice is emerging, particularly in the U.S. There is a strong realisation that the basics suited to the industrial revolution are no longer the correct focus for the potential citizens of the twenty-first century. This new "forward to basics" approach has the potential to satisfy the concerns of those outside the education system as well as those inside. The direct teaching of thinking is seen as one of these new basics.

IMPLICATIONS FOR SCIENCE EDUCATION

Back in 1954 Polya (1954a, b) pointed out that the typical mathematics textbook showed readers the deductive rigour of mathematical proofs but ignored the exploratory behaviour that originally led, often by complex routes, to the development of those proofs. In his many writings Polya (for example 1957) has outlined problem solving heuristics for general use in mathematical problem solving. Many of these heruistics are potentially widely applicable. De Bono's CoRT program is also essentially an heuristics approach. The heuristics are widely applicable in everyday life and business and management settings.

Probably the most notable effort in this area in science education was Science: a Process Approach (SAPA) developed by the American Association for the Advancement of Science in the 1960's. It used an activity centred approach to teach eight basic processes of science. The acceptance of SAPA by schools was very limited and research on the benefits of SAPA (Klausmeier, 1980) is discouraging. However, Klausmeier's work suggested that the program can work effectively providing student performance is monitored and further instruction is incorporated to amplify any revealed gains.

Looking at the results reported here in the area of academic achievement raises a problem for science education. De Bono (1976) has argued strongly that the CoRT program will have little effect in "knowledge-bound" areas such as science. These results support de Bono's contention. While science is taught as a relatively fixed body of knowledge to be learned and regurgitated it is almost impossible for generalisable thinking skills to show any real effects, particularly on performance in content-based examinations. It is clear that both the overall curriculum and the science curriculum need changing.

Pelz and Andrews (1976), in a large-scale study of the productivity of scientists in organisations, found that breadth of interest was characteristic of the more creative scientists. Mansfield and Busse (1981), in their impressive review of scientists and their work, found that personal flexibility and openness to experience were among the most significant personal characteristics of creative scientists. Despite such findings we find that in many states of Australia the most able secondary science students are studying only Science, Mathematics and English.

It is widely accepted among science teachers that the curriculum is far too packed with material they feel obliged to force-feed to their students. Collea and Nummedal (1980) asked: "Can a science curriculum be reorganised around specific thinking skills rather than scientific content?" Polya has shown how this can be done in mathematics. The first study reported here (Edwards and Baldauf, 1983) and work of researchers such as Larkin (1980) are beginnings in the science area.

A direct, and quickly implementable approach, is to use a program such as CoRT as a central core in the science program. This is already happening in some Australian schools. The diffusion of such a set of thinking skills through a science curriculum should produce students with an impressive array of focussed thinking skills. An alternative approach is to go to sources such as Mansfield and Busse (1981), Larkin (1980), or Edwards and Dall'Alba (1981) and begin the production of a taxonomy of scientific thinking skills which could then form one of the bases for a new science curriculum. The issues of teacher retraining and implementation strategies in this area could be well informed by the ongoing Australian research of Mitchell and Baird (see, for example, 1985) and the author of this paper.

CONCLUSION

The studies briefly reported in this paper reveal the enormous potential in the direct teaching of thinking for improving the thinking skills of students. Science education could be a powerful vehicle for such an approach. In the short term this could be achieved by incorporating an existing program such as CoRT as a core science curriculum element. The detailed study and reporting of such implementation efforts is important in suggesting ways forward. In the longer term, the design of new science curricula which have as a major focus the direct development of thinking skills should be a priority.

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SCIENCE AND ITS PROFESSIONALS: VIEWS OF AUSTRALIAN SCIENTISTS ON SCIENCE EDUCATION

Paul Strube

INTRODUCTION

Science educators often find themselves removed from the world of practising scientists. Yet it would seem appropriate that the content of science courses should reflect the actual practise of scientists themselves. Content here means not only the currently held views on matters of fact and theory, but also the aims of science and the ways such results are uncovered—the methodology of science.

Little research appears to exist on the practise of scientists as a guide to decision making in science education. Indeed, a complete demographic study of the Australian scientist has yet to be done, despite current interest in increasing the public role of science in Australian economic life. This study attempts to find out the views of Australian scientists concerning some general issues in science education. A sample of currently practising professionals in both the public sector—mainly universities-- and the private sector was asked to respond to a 30 item questionnaire dealing with three main topics. (1) The aims of science; (2) The practise of science; and (3) The education of scientists. Only the last of these topics is reported on here.

THE SAMPLE

At the outset, an apparently simple question raised interesting problems. Who is a scientist? The title itself, for instance, does not appear as a category on the Australian census form.

Is, for example, a pathologist, or an amateur beetle collector a scientist? To avoid debate over the matter, it was decided to use the definition of the Association of Professional Scientists of Australia (APSA), the trade union representing the scientists in private enterprise. In their terms, a scientist is anyone holding at least a B.Sc. degree who has been employed on the strength of that degree to work in a scientific or technical capacity. The APSA believes that of the roughly 25,000 scientists working in Australia, almost 50% of those are employed in the private sector.

Each recipient was asked to supply his or her age, area of research, and nature of employer—public or private.

1. Public sector scientists

These were sampled by selecting at random twenty faculty members from the science departments of every Australian university. The faculties selected were biology, chemistry, geology and physics, to correspond with the traditional content areas of school science.

Two hundred questionnaires were sent out, and 95 valid returns were received. The sample was structured as follows:

Researching in biological sciences:	53
Researching in physical sciences:	42

Age

29 years and under	1	(1 Phys)
30 - 39	19	(7 Phys; 12 Bio)
40 - 49	39	(24 Phys; 15 Bio)
50 years and over	32	(19 Phys; 13 Bio)
Not stated	4	(2 Phys; 2 Bio)
TOTAL	95	

2. Private sector scientists

These were kindly sampled by including a copy of the questionnaire in the APSA newsletter, which has a potential readership of 1,100 members. Only 66 replies were received. Due to a lack of supplied information, it was impossible to structure the respondants by research area; thus their results were treated as a whole.

Therefore the total number of respondants is 161.

THE QUESTIONS ASKED

There were six (6) questions dealing with the education of scientists. Each was to be answered by ticking a box corresponding to one of four choices.

1. Strongly Agree
2. Agree With Reservations
3. Disagree
4. Stongly Disagree

In addition, each question was followed by a space inviting comments, either on the question itself or on the answer given.

Question 1.

My experiences with primary and secondary school science were crucial in my eventual career choice.

This question was posed to gain some idea of the influence of science education on career choice in science, conceding that science education has rarely seen its main purpose as preparation for professional science.

Question 2.

Success at research is more common among scientists who have received some training in research methodology, either at school or from a professional already practising.

Do professionals believe that research methodology can be taught, in any fashion, or is it acquired in some other way?

Question 3.

In my primary and secondary school science education, I now wish I had been taught more research skills and less facts.

This was, as it turned out, poorly worded, containing two items for response. It was posed to gain some idea of how professionals see the current debates over 'product and process', or 'enquiry' as a legitimate endpoint for science education.

Question 4

Science education at the primary and secondary level should pay greater attention to fostering attitudes supportive of science (e.g, curiosity about natural phenomena, rational approaches to evidence).

Give that there is concern over the willingness and ability of the general public to competently debate current social issues involving science (such as IVF), would scientists like to see greater attention paid to increasing the public's respect for scientific approaches?

Question 5

Science education at the primary and secondary level should pay greater attention to the professional life of scientists (e.g., science as a career), rather that just the results and methods of science.

Should science education take more interest in science's professionals; is there a need for a greater public profile of scientists; would science be better understood by making it more obviously a career entered upon by ordinary people for many reasons?

Question 6

Every child at school should be taught about the social implications of science as well as the results and methods of science.

In line with current interest in Science, Technology and Society curricula, it would be of importance to know if scientists feel that their work has social implications, and that these should be reflected on in schools.

RESULTS

Each question was analysed by age, sector of employment, and area of research (physical or biological sciences). However, to give a general idea of overall response to the questions, Table 1 provides mean responses for all scientists.

TABLE 1

Mean Responses for all Scientists

		Mean Responses
1.	My experiences with primary and secondary school science were crucial in my eventual career choice.	2.42
2.	Success at research is more common among scientists who have received some training in research methodology, either at school or from a professional already practicing.	2.70

TABLE 1
Mean Responses for all Scientists (Cont'd)

		Mean Responses
3.	In my primary and secondary school science education, I now wish I had been taught more research skills and less facts	3.10
4.	Science education at the primary and secondary level should pay greater attention to fostering attitudes supportive of science (e.g., curiosity about natural phenomena, rational approaches to evidence).	1.87
5.	Science education at the primary and secondary level should pay greater attention to the professional life of scientists (e.g., science as a career), rather than just the results and methods of science.	2.83
6.	Every child at school should be taught about the social implications of science as well as the results and methods of science.	1.93

Note: Responses ranged from 1 (strongly agree) to 4 (strongly disagree). Thus, the lower the mean response, the stronger the agreement.

The responses show little overall support for the value of schooling in career choice; nor do they see it as having an strong influence on success in research. In fact, it is clear they see the role of the science curriculum as providing knowledge and factual material rather than emphasising methodology. Many written comments accompanying question 3 indicated that facts are the necessary base for research, and should be rigorously taught.

Not surprisingly, many scientists were in agreement with the suggestion that science education should attempt to encourage 'scientific attitudes' for dealing with the world. This, combined with emphasis on factual knowledge, may be considered to set the guidelines for the science curriculum.

Comments accompanying question 5 suggested that the negative responses were based on the feeling that there is not enough time in the science timetable for attention to be spent on scientific careers.

Again, comments with question 6 indicated that, while social implications are very important, it is not the concern of the science teacher, but of the social sciences teacher. There was some contradiction, however, with some respondants expressing concern that the social science teacher would not treat science with sufficient impartiality.

Of particular interest was the possiblity that scientists practising in different areas of research might answer the questions from such different perspectives that their answers could be used to discriminate between them. Included in this is the alternate idea that sector of employment might also exert selective influences on the answers. Table 2 shows the data when analysed for these factors.

TABLE 2

Percentage Responses by Sector of Employment and Area of Research

	PUBLIC				PRIVATE			
	Physical Science		Biological Science				Totals	
	+	-	+	-	+	-	+	-
Ques. 1.	71.7	25.6	47.6	47.4	59.1	36.4	60.2	36.7
Ques. 2.	64.1	26.4	64.3	21.4	66.7	24.2	65.3	24.2
Ques. 3.	22.6	71.7	35.7	59.5	41.0	48.5	33.5	59.0
Ques. 4.	86.8	5.7	95.2	2.4	89.4	4.5	90.0	4.3
Ques. 5.	45.3	49.0	42.8	50.0	53.0	39.4	47.8	45.3
Ques.6.	83.0	13.2	88.1	7.1	87.8	7.6	86.3	9.4

Note 1: 'strongly agree' and 'agree with reservations' and 'diasagree' and 'strongly disagree' have been collapsed into agree (+) and disagree (-).

Note 2: % may not add to 100 because 'no response' percentages not included.

The largest discrepancy within sector of employment concerns question 1; physical scientists in the public sector indicate a much stronger influence of schooling on career choice. It is tempting to suggest that, quite simply, in what other ways are most students exposed to the physical sciences— a traditionally laboratory based subject—except in schools?

On other questions, there was considerable agreement. A final look at the data provides the opportunity to see if the age of the respondant has influenced the answer.

TABLE 3

Percentage Responses by Sector of Employment and Age of Scientist

Age	PUBLIC				PRIVATE		TOTALS	
	Physical		Biological					
	+	-	+	-	+	-	+	-
Ques. 1.								
Under 29	0	100	—	—	70.0	30.0	63.6	36.4
30 - 39	71.4	14.3	41.7	58.4	63.6	31.8	58.6	36.6
40 - 49	83.3	16.7	66.6	33.4	55.0	40.0	69.6	28.8
Over 50	63.1	31.6	38.5	61.6	—	—	53.1	43.8
Unstated	50.0	50.0	0	100	50.0	42.9	44.5	50.0
Ques. 2.								
Under 29	0	100	—	—	80.0	20.0	72.8	27.3
30 - 39	71.4	14.3	75.0	25.0	72.7	22.7	73.2	22.0
40 -49	66.6	20.8	53.4	13.4	70.0	15.0	64.4	17.0
Over 50	63.2	31.6	61.6	70.8	—	—	62.5	31.3
Unstated	50.0	50.0	100	0	42.8	42.9	50.0	38.9
Ques. 3.								
Under 29	100	0	—	—	50.0	50.0	54.6	45.5
30 - 39	28.6	57.2	41.7	50.0	45.5	45.4	41.5	48.8
40 - 49	29.1	66.6	26.7	66.6	40.0	55.5	82.2	62.8
Over 50	10.5	84.2	38.5	61.6	—	—	21.9	75.1
Unstated	0	100	50.0	50.0	28.5	42.9	27.8	50.0
Ques. 4.								
Under 29	100	0	—	—	80.0	20.0	81.8	18.2
30 - 39	71.4	14.3	100	0	90.0	4.5	90.3	4.9
40 - 49	91.6	4.2	93.3	0	95.0	0	93.2	1.7
Over 50	84.2	5.3	100	0	—	—	90.7	3.1
Unstated	100	0	50.0	50.0	85.7	0	83.3	5.6
Ques. 5.								
Under 29	100	0	—	-	50.0	50.0	54.6	45.5
30 - 39	14.3	71.4	58.3	33.3	63.6	31.8	53.7	39.1
40 - 49	58.4	37.5	46.7	46.7	50.0	45.0	52.5	42.4
Over 50	42.1	52.7	23.1	69.3	—	—	34.4	59.4
Unstated	0	100	50.0	50.0	42.8	35.7	38.9	44.5

TABLE 3
Percentage Responses by Sector of Employment and Age of Scientist
(Cont'd)

	PUBLIC				PRIVATE		TOTALS	
Age	Physical		Biological					
	+	-	+	-	+	-	+	-
Ques. 6.								
Under 29	100	0	—	--	100	0	100	0
30 - 39	85.7	0	91.7	8.3	86.3	9.1	87.8	7.3
40 - 49	91.6	8.3	93.3	6.7	90.0	5.0	91.5	5.1
Over 50	68.4	26.3	84.7	15.4	--	—	75.0	18.8
Unstated	100	0	50.0	50.0	78.6	14.2	77.8	16.7

Note 1: 'strongly agree' and 'agree with reservations' and 'disagree' and 'strongly disagree' have been collapsed into agree (+) and disagree (-).

Note 2: % may not add to 100 because 'no response' percentages not included.

There are not many clear trends in the data with respect to age. Some general comments can be made, remembering the small size of the sample perhaps renders these as possibilities for further analysis.

1. There is some evidence to suggest that those scientists at school either most recently, or 20 to 30 years ago, remember schooling as being of some positive effect in their career choice—especially the physical scientists in the public sector. Thirty years ago, of course, was the dawn of the Sputnik era, and twenty years ago was the lunar landing era.
2. With question 2, there is a slight drop with age in the belief that research methodology can be taught, though biologists coming to the end of their careers are more accepting of the idea. Interestingly, private enterprise scientists are the most convinced, at any age, that it can't be done.
3. Question 3 is very interesting. It shows the physical scientists most concerned with the teaching of facts, and it reveals a contradiction in the private enterprise scientists, who, while they thought methodology can't be taught in question 2, are quite evenly divided on thinking it's a good idea to teach more of it.
4. Question 4 shows the physical scientists slightly less happy with the idea of teaching attitudes supportive of science, though such support does increase with age.

5. It could be argued that biologists show increasing reluctance to discuss biology as a career in schools as they advance through their careers, while physical scientists show some increased desire to do so. And while the private enterprise scientists in general are more in favour of the idea, those in the middle of their careers are the most enthusiastic of all.
6. The social implications of science are a matter of greater concern to younger scientists in particular, but the effect does not seem strongly affected by age.

CONCLUSIONS

This study raises a great number of questions, many of which would be valuable for science curricula to reflect upon. Firstly, it would seem that the practising professionals do not believe methodology is easily taught, at least not without a strong factual knowledge base. Secondly, science courses have had little effect on career choice, with the possible slight exception of physical scientists working in the public sector. Thirdly, scientists would give strong support to the idea of teaching students to use 'scientific attitudes' in their everyday life. And fourthly, the social implications of science are felt to be deserving of close attention in schools—but perhaps not within the science classroom.

What clearly remains to be done is the difficult and time-consuming work to follow up these hints. What do the scientists see as the scientific attitudes? What facts, etc., should form the basis of the science curricula? How should the social implications of science be discussed, and what responses are appropriate to them? To answer these questions will take a national study of great scope and effort, yet it would seem to be an essential part of the process of determinng science education programmes of purpose and value.

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DRAWING OUT IDEAS: A NEGLECTED ROLE FOR SCIENTIFIC DIAGRAMS

Richard K. Lowe

Diagrams and other forms of pictorial representation are a significant component of many science lessons. It appears that the pictorial language which characterises teaching materials used in such lessons is often assumed to be far more immediately accessible than written language. This assumption is emodied in the frequent use of pictorial presentation in what Levie and Lentz (1982) describe as a 'compensatory' role whereby pictorial material is included for less capable readers as an alternative means of access to key information. However these authors also point out that there are classes of pictorial material, such as certain types of diagrams, for which the assumption of relatively transparent meaning can lead to an inadequate understanding of the author's message.

VISUAL LITERACY IN SCIENCE

The concept of visual literacy that has been adopted by a number of authors reflects the view that many pictorial materials are not nearly as unproblematic as is popularly assumed (Fleming, 1979; Sless 1978,1984). The nature of this concept can be clarified by reflecting on the current meaning of literacy as it is used in the context of written language.

To be literate in written language means that a person can not only read written language successfully but also can write (or construct) effective written language. The combination of economy, rigour and structure that is the hallmark of the formal expository writing found in science textbooks demands different reading skills from those required for more informal narrative writing genres. Students must clearly be able to comprehend written material in science textbooks that exhibits these formal characteristics. In addition to reading, it is also expected that students in school science classrooms will develop the capacity to write in a way that to some degree resembles the characteristics of formal scientific communication. Such an expectation reflects the wider goal of helping students develop the knowledge and skills that will raise the level of scientific literacy within the general community (Miller, 1983). It is clear that literacy in the context of the science classroom cannot be adequately characterised by the catch-all meaning attached to the term 'literacy' that permeates popular culture. To be able to read and write effectively in science lessons requires certain specialist knowledge and skills that distinguish the classroom scientific genre from other written genres.

Literacy in visual language is often thought of in terms of the capacity to read diagrams and similar pictorial material. However, it can also be seen as having a 'construction' component analogous to the writing component of literacy in text-based language. The pictorial representations used in science are characterised by distinctive approaches that parallel the distinctive characteristics found in scientific writing (Lowe, 1986). Because scientific diagrams effectively constitute a particular genre of pictorial material, visual literacy in science has a specific meaning that could not be applied to other visual genres such as fine art. 'Reading' and 'writing' scientific diagrams are specialised tasks. Although one can find some token attempts in recent science curriculum guidelines to address broad diagram interpretation ('reading') skills, there appears to have been no systematic attempt in general science education at the primary or secondary level to ensure students develop a comprehensive set of diagram construction ('writing') skills. I should emphasise here that I am not talking about transcription or formula processes ("Copy the diagram for the production of CO_2 from marble chips", "Draw a diagram of the magnetic field around a bar magnet") but about a compositional process.

The consequences of a deficiency in visual education for science learning are not as immediately apparent as would be deficiencies in text reading and writing skills. However, in the longer term, the student's capacity to grasp and manipulate more sophisticated scientific concepts and relationships may well be impaired as the result of such a deficiency. This possibility has been raised by Sless (1981) who has highlighted the limitations that the lack of an adequate visual education imposes on the range of conceptual tools available to science students.

Although it is standard practice to address the development of literacy with respect to written text by means of an extensive programme of formal instruction, this is clearly not the case for visual literacy. There is a clear assumption that students' educational progress depends mainly upon the development of literacy skills centred on written language. The topic of visual literacy remains a backwater in educational practice, despite the increasing theoretical interest in pictorial components of instruction.

DRAWING, SCIENCE AND COGNITION

The task of drawing a scientific diagram can broadly be divided into two main subtasks or components: the 'drawing' component and the 'scientific' component. Each of these components involves a special set of requirements. The drawing component requires the person who is drawing the diagram to solve problems such as how to depict the individual diagram elements and how to arrange them with respect to each other. However, the scientific component requires the drawer also to manipulate aspects of the drawing component in such a way that scientifically important relationships within the diagram are accurately represented. Although in more decorative types of drawing such as artistic sketching it is sufficient that the product is a recognisable depiction of the subject matter or is aesthetically pleasing, this is not enough for a scientific diagram. A diagram will be scientific nonsense if key relationship have not been represented accurately. Even if the global impression was convincing, such a diagram would not stand up to the scrutiny of analysis from a scientific point of view.

The contrast between the drawing and scientific components of the task of drawing a scientific diagram may help to explain why students who reproduce 'accepted' versions of diagrams devised by an authority sometimes seem to display a lack of understanding in what they have drawn. It is possible that students whose main experience of drawing scientific diagrams has been in a 'copying mode' habitually address their efforts toward the drawing component of the task to the exclusion of the scientific component. The classroom regime may encourage students to attend to the global aspects of their drawing rather than to the frequently less-obvious, but critical, scientific relationships that should be embedded in the diagram. It is also possible that the cognitive demands of the drawing component of diagram contruction may prevent a proper consideration of the scientific component. The study of cognition during the drawing process is a comparatively neglected research area, but the work of van Sommers (1984) supports the view of drawing as a cognitively demanding enterprise. Van Sommers argues that, at one level, drawing may be considered as a sophisticated problem-solving activity in which a variety of complex cognitive operations act in concert to address the interwined semantic and syntactic dimensions of the drawing process. If the cognitive demands of drawing a neat and globally faithful copy of an authorised diagram are very high, then it is plausible to suggest that little cognitive capacity will remain for processing the associated scientific aspects of the diagram. There appears to be a potential for conflict between the cognitive demands of the drawing process itself and the cognitive utility of drawing as a tool for exploring scientific ideas.

LANGUAGE AS A COGNITIVE TOOL

In written language, the process of constructing prose can function as a means of clarifying the writer's ideas with respect to the phenomena described or the theories proposed. The distinction between writing for the purpose of communication and writing as a means of exploring ideas is embodied in the concepts of transactional writing and expressive writing proposed by Britton (1975) as a means of clarifying the different functions that writing can have in the educational process. The active working at text involving its modification and various transformations can help the student delineate concepts and establish or clarify relationships between concepts.

The potential of language to facilitate thinking and learning is made clear by Bruner and Olson (1973). These authors argue that learning through written and other forms of symbolically coded language has characteristics that distinguish it from learning through direct experience or observation. Because language allows concepts and processes to be abstracted from the bounds of their specific contexts, it can act as a powerful cognitive tool for instruction. Not only are there differences between symbolic language and other ways of finding out about the world, there are also differences between individual symbol systems themselves and how they interact with the learner.

Different symbolic languages are characterised by different semantic and syntactic conventions. Although written languages such as English and mathematical notation have quite formal sets of rules, other systems of expression are less constrained. In particular, the various forms of pictorial representation we interact with are often governed by flexible conventions of coherence rather than by the prescription of formal rules that characterises more unambiguous forms of communication (Salomon, 1979). The presence of a well defined, more or less fixed rule structure in a symbolic language can help to minimise misunderstandings during communication between those with similar literacy in that language.

LIMITATIONS OF WRITTEN LANGUAGE

However, there is a disadvantage of a formally structured symbol system when such a language is used as a personal cognitive tool rather than as a vehicle for communication. The very constraints that facilitate communication between individuals using a common prescriptive symbol system may also have the capacity to restrict the manipulation of ideas.

If we consider written text as an example of a highly constrained language governed to a large extent by prescriptive rules of construction and meaning making, we can readily see why it may restrict thinking in certain situations. An important characteristic of written language is its serial nature in which ideas follow each other in a fairly regulated order. The opportunities for spatial manipulation of ideas are limited. In many situations such as in the logical exposition of an argument or the sequencing of events into a narrative, this serial characteristic is highly advantageous. However, as a means of playing with ideas, treating information in a parallel manner, looking for new connections and varying one's focus from global matters to a more analytical approach or vice versa, written language can be comparatively clumsy medium.

Diagrams offer a flexible and powerful alternative to the written word as a medium for novel and complex thinking. The match between the highly developed sense of pattern that characterises human visual information processing and the capacity of pictorial representations to organise complex information into patterns has been used to account for the utility of diagrams as a cognitive tool (Sless, 1981).

MENTAL IMAGES AND DRAWING

The advantages of thinking in science with images rather than with words are discussed by Shepard (1978) who cites examples of eminent scientists who apparently found that the use of images was expecially useful in the process of creating new ideas. It seems from these examples that new scientific ideas can arise from a relatively unconstrained process of mental exploration involving images. An interesting and important example reported by Shepard is that of Einstein who maintained that his translation of ideas into words occurred relatively late in his thinking process, well after the important work of exploring ideas with images had been accomplished.

Although thinking with images appears to have been an important aspect of professional cognition for many eminent scientists, the manipulation of mental images can be a difficult business (Shepard & Cooper, 1982). Complex manipulations of images seem to be subject to the limitations of working memory capacity in a way that is similar to what is found with other forms of sybolic manipulation such as mental arithmetic. Because our cognitive processing is constrained by the limited capacity of our working memory (Keil, 1984), we commonly resort to using an external 'memory' in the form of paper working when we are faced with arithmetic manipulations involving multiple digits or a succession of operations. It appears that many creative thinkers in science have used a similar cognitive ploy by drawing diagrams. Sless (1981) links the external process of drawing to the internal processes of visual thinking, seeing it as a valuable extension of, and supplement to, these internal processes. Macdonald-Ross (1979) attributes a key role to scientific diagrams in the progress of scientific thinking. He maintains that diagrams can provide fresh insights into situations being studied and thus facilitate the appreciation of new relationships that were not previously apparent.

The history of the development of drawing as an external adjunct to thinking, especially in science, provides some useful insights into why drawing may be more important in science learning than is currently realised. The blossoming of scientific activity in the Renaissance has been accounted for in terms of a direct and working relationship between the art of the period and its science. Edgerton (1980) has argued that the new techniques of pictorial representation developed during the Renaissance changed the way intellectuals thought about the physical world and introduced sophisticated ways to depict quantative aspects of natural phenomena. Not only did these developments provide new tools for scientific thinking, they also provided richer and more precise means by which individuals could communicate about scientific matters.

During the Renaissance, new methods of depiction such as the 'transparent view', the 'rotated view' and the 'exploded view' were developed and used to facilitate thinking about structures and functions in the physical world. These graphic techniques gave people more powerful and varied ways of thinking about the subject matter in situations that were removed from the context of the subject matter itself. As previously noted, this independence from the tyranny of specific contexts was one of the strengths that Bruner and Olson (1973) attributed to language as a means of learning.

By recording a visual representation, transient phenomena could be frozen in time and space and so be reflected upon at leisure. Complex phenomena could be unpacked into simpler components so that they were more amenable to analysis. Existing situations could be modified on paper thus providing the facility for speculative exploration and the opportunity for new and useful insights. The possibility of completely new developments could be represented in pictorial form and explored without the immediate need to deal with the subject in a fully concrete form. Although some of the cognitive opportunities provided by this expanded role of drawing were already available in written language, the great power of pictorial language was that it was such a flexible medium for thinking.

In the final section of this paper, an attempt will be made to reconcile the well-documented but largely anecdotal and post hoc historical interpretations of the utility of diagrams in scientific thinking with a cognitive view of learning in science. The synthesis will be undertaken not in the context of distant famous scientific discoveries but in the context of students discovering scientific concepts and principles during their individual learning experiences. The unfamiliar ideas that science students must grapple with may well be novel to these students in a manner analogous to the way the powerful new ideas of scientific revolutionaries were novel to their originators. A scientific idea that is new to an individual student is no less novel to that student by virtue of it being 'old-hat' to the established scientific community. In a sense, students throwing off the shackles of their alternative frameworks and coming to grips with conventional science involves personal scientific revolutions that in many ways parallel those revolutions in thinking associated with landmark discoveries of eminent scientists in the past.

EMBEDDING SCIENCE IN DIAGRAMS

It appears that students sometimes fail to appreciate the key role that relationships play in scientific diagrams (Lowe, 1987). One way to interpret this is in terms of a failure to form links between different types of information storage within the student's cognitive structure (Gagn'e and White, 1978). Deficiences in linking information in the form of images with information in the form of propositions could help to explain why some students have a limited understanding of scientific diagrams. If such deficiences exist, then it would be important to devise new approaches to the teaching of diagrams in science to facilitate this linking. Although not specifically concerned with images and propositions, the work by Mackenzie and White (1982) on linking of episodic material with classroom lessons suggests what general sort of approach may be successful. Mackenzie and White found that an excursion incorporating activities that encouraged active processing of information was far more successful than a passive excursion format in helping students retain information from an associated classroom lesson. The gains achieved by the use of vivid episodes linked to classroom lessons may also be possible with images, provided students engage in active learning experiences that facilitate intense, integrative processing of information in the form of images and propositions.

Gagn'e and White (1978) have hypothesised that image-processing tasks such as drawing may be able to deepen students' understanding of subject matter because of the potential of these tasks to generate such links. I will assume from the emphasis give by Gagne and White to active processing of diagrams that their advocacy of diagram drawing by learners does not include purely transcription process such as copying or tracing. However, the task of creating, revising and polishing an original diagram that encapsulates an important scientific concept or process could provide suitable opportunites for linking different forms of encoding.

The task of devising an original scientific diagram accords well with the conception of science learning as a generative process (Osborne & Wittrock, 1983, 1985). This generative view provides a convenient framework for a consideration of the way in which diagram construction activities could help to link image representation of scientific subject matter with other aspects of cognitive structure. An important feature of the generative learning model is that tentative meanings are constructed and evaluated along the way to the construction of a final meaning. The testing of the series of tentative meanings constructed during this process is carried out by checking them against both internal long-term memory information and external information derived from the senses.

The short-term memory is seen as the locus of this generating and testing activity. If relations are the basis of all meanings (Pines, 1985), then generation and testing of tentative meanings must involve various mental manipulations of the variables comprising the relations upon which those tentative meanings are based. However, because of the limited capacity of working memory, many students would probably face great difficulties in attempting in a single pass to link image and other forms of representation. Because of the significant demands of the cognitive processes involved in the drawing process itself (van Sommers, 1984), it appears likely that short-term memory activity concerned with this task alone may effectively consume all available capacity during the drawing of a diagram. If a student's attention and cognitive resources are fully occupied in solving external image construction problems then it is unlikely that the additional problem of linking the image to propositions would also be addressed. What appears to be needed is a facility by which students can control the cognitive load they are under in such a way that the limits of working memory capacity are not exceeded. If the task of making all the necessary links between images and propositions contained in a situation at the same time as controlling the drawing process is too demanding, then clearly the task needs to be broken into a series of subtasks. By working at the diagram as a series of drafts which are external to the student, he or she would be able to choose a level of interaction with the image and/or propositions that is appropriate to the stage reached in developing a tentative meaning. Because information that is no longer the subject of immediate interest is stored in a permanent external 'memory', there is no chance that the results of prior manipulations will be lost when cognitive room has to be made in working memory for new manipulations to occur.

The results of previous individual small scale manipulations could be built up on the external image to form permanent large units of meaning. Later, various conglomerations built up as a result of a series of individual mental manipulations could be conceptualised as single chunks and themselves be manipulated in working memory without causing cognitive overload. During each processing cycle, the student may have to either (a) share attention and available working memory capacity between drawing components and scientific components of the task or (b) focus attention and allocate capacity mainly on either the drawing process or the development of propositional relationships. As the external image builds up, so internal images and propositions would be intertwined into something akin to what Anderson (1983) has characterised as a mixed and tangled hierarchy of different types of representation. These external and internal developments would occur in concert during the recursive revision of the external image.

DEVELOPING IDEAS THROUGH DRAWING

Consideration of the many and varied roles that drawing can serve in manufacturing industry is a useful way to highlight the range of instructional opportunities drawing could provide in science instruction. Sless (1981) has described the way the depiction of an article to be manufactured changes and develops through a succession of progressively refined drawings. The progression from a rough sketch of a basic design concept to a details and fully docmented set of final manufacturing specifications reflects different stages of thinking about the project. Initially, drawing can assist the designer's first attempt to externalise the vague and almost intuitive personal grapplings with the problem at hand. These initial sketches then provide a basis for further drawing involving the exploration and elaboration of this first primitive conceptualisation. Ultimately, drawings must be produced that will communicate manufacturing instructions in an unambiguous fashion to the production facilities at the shop floor level. Between these initial and final stages, the function of drawing undergoes a significant change as the conception of the product is developed and refined.

In the early stages, drawing is used as a tool for thinking about developing ideas whereas in the later stages it is used as a vehicle for communicating the refined outcome of that thinking. This change in function from a process to a product orientation has important implications for the way we view drawing in science lessons. Much of the drawing activity in which students are engaged during science lessons is concerned with the reproduction of an acceptable final product that is neat, free from errors and accords with accepted diagrammatic conventions. Such diagrams are rarely the outcome of active cognitive exploration of the subject matter by students because the early stages of drawing described in the previous example of the manufacturing design process are are absent. It seems likely that students often perform a role somewhat resembling that of a person making neat transcriptions of routine drawings in a drafting office. All the more demanding thinking has already been done and the person drawing is doing little more than copying an arrangement of shapes. This is not to say that there are no beneficial outcomes from conventional approaches to treating diagrams in science teaching. Clearly many students cope very well with these methods. The key to their success is probably that such students engage in cognitive processing of diagrams at a depth that is sufficient to produce understanding. However, it is also clear that for other students, teaching involving scientific diagrams remains an area of limited instructional effectiveness. A change in emphasis from passive copying to active construction of scientific diagrams, as a general principle, has the potential to make learning in science more meaningful and better integrated. This potential should now be explored empirically with the ultimate aim of making instruction in this important but neglected area of scientific thinking more effective.

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CLEAR THINKING AND SCIENTIFIC METHOD FOR OUR FUTURE LEADERS

Rod Fawns

In the midst of the furore about the introduction of a common General Science at senior level in Victoria in 1987, an opponent in Melbourne University said to me:

> "We have Clear Thinking where the students can discuss Science in its social context."

I recognized the historical roots to this argument. Clear Thinking is a long-lived and potent curriculum invention of the thirties promoted by several prominent scientists at that time. It had a similar message to General Science about education for citizenship (Fawns. 1985). Clear Thinking was a central element in attempts at reform of the teaching of senior English which, in the old humanist curriculum, was rooted in literary appreciation and language comprehension rather than human concerns and interests. The treasury of English literature was held by the old humanists to reveal the true human spirit, as well as to illustrate exemplary models of language practice.

In 1939, the Melbourne University Schools Board, influenced by Wadham & Wright, proposed the separation of English Expression and Literature as part of the new scheme of examination at Intermediate which was to provide for wider public interest and participation. General Science as a subject was conceived in this context. Professor Cowling, Chairman of the English Standing Committee of the Board, who had just returned from leave in England, sent a memorandum of protest to the Board in which he indicated the sort of tradition he sought to preserve and his perception of the challenge posed by democratisation.

> "I think that the English Literature should be taught in all schools until school leaving age for its emotional and aesthetic values. I think too that the thought and life of our ancestors is worthy of study not only for its inherent interest, but for its bearing on the problems of the present day. I am certain that Victorian education will suffer a spiritual loss, if, in future, English is to be taught as merely "expression" and not as understanding, communication and the appreciation of literature of the past. . . . .

> The Spens Report in demanding a parity of status for Grammar Schools, Technical High Schools, and Modern Schools appears to be justified in the report by the democratic tendency of the age and the necessity of limiting the supply of clerical workers in favour of scientists and technicians. In like fashion the Schools Board recommends the same type of examination in English for all kinds of Victorian schools. It wishes to make the test simply one of communication and understanding. This, in Australia, is not wise . . .There is, or should be, a literary tradition in the High Schools and Public Schools. The tradition in the Technical High Schools is, or should be, scientific. . . . .The problem of what and how English is to be taught to children of middle class parents (in Australia) is quite different . . . . The habit of reading works of literary merit is more widely prevalent in England. . . Fortunately the other States show no signs of such short-sightedness..." (Cowling, 1940).

In 1940 Cowling proposed a trade-off. He wrote to Browne that "the Standing Committee in English has embarked on a new policy of encouraging their pupils to think clearly and to express themselves accurately" and that for this purpose he had set a book in "Thinking and Expression" at Leaving but that he wanted an extension of examination time. Cowling was successful in holding expression and literature together as English at Intermediate and Leaving level, but fewer literary works and more "gobbets" as he called these books of short pieces, were set.

The pioneering texts for this innovation in English were a psychologist Thouless's Straight and Crooked Thinking in 1930 and Jepson's Clear Thinking in 1936. The investigation of social problems was implicit in the movement and probably as a result became a part of senior English. Thouless wrote his text initially for an adult audience. The purpose of the book, he wrote,

> "is to deal with the kind of problem in which cold and detached scientific thinking is required. Most of the practical problems of life are of this order. The fact that I shall choose the use of emotional thinking in connection with such problems as tarrifs, prohibitions, social ownership, and war does not mean that there is no place for emotional thinking. Poetry, romantic prose, and emotional oratory are all of inestimable value, but their place is not where responsible decisions must be made . . . Real domocracy will come only when the solution of national and international problems is carried out by scientific methods of thought purged of all irrelevant emotion."

In subsequent chapters Thouless expounded the need for proof from the impartial researches of experts in a chapter entitled "All and Some," the abuse of authority in "Tricks and Suggestions," the value of the unorthodox, the unconventional and flexible mind in "Habits of Thought," the dangers and value of journalese in "Tabloid Thinking," the "Pitfalls in Analogy," the need for practical examples in "Vagueness and Related Evils," and illustration of special pleadings in "Prejudice." This eloquent book concluded with a plea for straight thinking and an attack on complacency in "Muddling Through".

> "We can solve the problems of war and poverty if we approach them in the same scientific spirit as we have now learned to apply to disease, sure that every effect has a cause, and that impartial scientific investigation will reveal those causes and that sufficiently determined effort will remove them . . . . nothing should stand in the way of their removal - no old tradition and none of the ancient priveleges which are called "right" by their holders. . . . but the revolution will start in our minds."

Thouless faced, he said, "the difficult choice between taking his examples of crooked thinking from live controversial questions such as politics, and choosing them from the hackneyed and trivial sources favoured by the academic textbooks." In this regard Thouless took the radical approach acceptable in adult education. He spoke out against the twin "social sins" of war and poverty. Jepson and Stebbing made the latter, safer choice. Their books were, unlike Straight and Crooked Thinking, written specifically as school texts. Jepson's Clear Thinking was first published in 1936 and presented in an Australian impression in 1946. It remained alongside Thouless a recommended text in Fifth and Sixth Form English Expression into the mid-sixties. Whereas school science textbook authors steadfastly denied any responsibilitiy to raise the level of public discussion about the role of science in social change through the period, such issues were taken up in these compulsory English classes through clear thinking and later anthologies of contemporary social comment.

The occasional questions such as the following from the 1945 Leaving Certificate Examinations of New South Wales illustrate the new balance being sought in English Expression between language as a tool and set of rules.

a) Compose a letter of about an average page (150 words) in length, addressed to the Editor of "The News," in either support or condemnation of the use of the atomic bomb warfare. In it incorporate, though not necessarily in the same order, any FIVE of the following words, and then add notes, explaining very briefly what you understand the five words to mean:

   Misgiving; aggressor; reprisal; insidious; remonstrances; asiduity; detestation; repugnance; infallible; prejudice; sceptical; beneficent; contentious; intolerable.

b) Define the following terms, and illustrate them briefly by giving or citing an example:

   Personification, Metaphor, Hyperbole, Allergory.

Thouless's suggestion that authors examine controversial questions rather than choose the hackneyed paradigms seems never to have been made in school science, even in the thirties & forties. Ashby, Stanhope and Turner were arguing for a rejection of "hackeneyed and trivial" science in favour of a relevant rather than controversial science but a Science For All, organised around social themes, in the American style, war as Turner explained in the preface to General Science for Australian Schools, not feasible in Australian schools of the forties.

General Science in the reformers view was to serve society in a practical way. It was to provide, in the most efficient arrangement, the technical knowledge demanded of a new curriculum. Positive knowledge and values and direct method were to be provided in general science for the citizenry. The social function and world view of science was to be left to the explication of the English teacher.

For his part, Jepson was keen to extend what he saw as the advantages enjoyed by science students in their logical training to all senior students. Writing for the grammar school Sixth, he acknowledged the influence of the Training for Citizenship Movement.

> The citizen of democracy also needs certain intellectual qualities. It is not enough to love truth; he must learn how to find it. It is easy to reach students to reason correctly in the physical sciences; it is so much more difficult to teach them to reason correctly in the social sciences where their own prejudices and passions are involved. They must be taught habits of clear thinking in order that they may acquire the power of reorganising their own prejudices and of discussing political and economic questions with the same calm, the same desire to understand the other person's position, the same precision and absence of overstatement, as they would bring to the discussion of a problem in mathematics."

Jepson claimed his approach was an adaptation of that recommended in Education and Citizenship. This amounted to a somewhat negative, studious neutrality and scrupulous criticism of committed social argument against obvious errors, pointing them out when they were committed, leaving the pupils to make the positive effort for themselves. The traditional values of intellectual distance and self-help were to be maintained. The need for clear thinking was introduced by Jepson in terms of extending the clear thinking of natural science that he saw as having "overcome the opposition of ignorance, suspicion and prejudices which block the way to progress in the social sciences, and the establishment of a just and durable peace".

> One of the ways in which we may hope to solve the political, social and economic problems is with the same critical, disinterested and unprejudiced attitude in which scientific men have carried out their labours and research and reported the results of them to the world. We want more honest and purposive thinking and the results of it expressed in clear and unequivocal speech and writing".

A central chapter in Jepson's original course was a lecture delivered by T.H. Huxley in the mid-nineteenth century in which was elaborated his celebrated definition of the scientific method as "nothing but trained and organised commonsense of the common man".

> "the mental process by which scientific achievements have been attained were not rare, uncommon or abstruse processes peculiar to the scientific mind, but differed only in degree from those practised by every one of us in the humblest and meanest affairs of life. What is called scientific method is merely trained and organised commonsense."

Jepson's original purpose of clear thinking was:

> "to examine and analyse the mental processes of scientific method; to learn a little of how the mind works; how knowledge is acquired and widened; how judgements are formed and how they should be applied; and how mistakes are made - in other words the mental processes of commonsense; and in the course of this examination and analysis we shall find ourselves learning a little of psychology and logic".

As we have seen, the attraction of General Science as a school subject to James Darling, in the forties, was its commitment to the presentation of a practical way of thinking which did not threaten internalised cultural values, and protected the literary culture from what they saw as technical fragmentation.

To Darling the influential Principal of Geelong Grammar School such a way of thinking was appropriately, humble and naive. Further, it fitted in well with the familiar values of nineteenth century liberalism, methodological individualism, and free choice. Such a view of the social function of school science to inculcate a "way of thinking" or a "method" was attractive as an instituational solution to the problem of redefining the liberal curriculum challenged by the growth of scientific knowledge. By treating science as the way technically-minded people deal with technical problems, the old curriculum form, which identified subjects with qualities of character or personality, was undisturbed. Part of the acceptable solution as we have seen was to leave political and moral training where it had always been: in literature and history, in the study of human nature and purposes. A more limited scope for school science seemed appropriate and acceptable to the teachers.

The Danger of Technical Frgmentation and Intellectual Vandalism

Behind both the Clear Thinking and the General Science movements stood that belief that knowledge was all one, "thinking" being an interchangeable handle to the tools used in various branches. The attainment of human welfare was advanced as the common integrating purpose. The danger often acknowledged but to different ends addressed was that knowledge, continuously developing, expanding and transforming human understanding, might develop in water-tight departments and thus fragment the liberal education. "Is it not preferable," asked Jepson, "to develop an interchangeable technique of thought to orientate all departments of study to a common aim? Then if the specialists share this common aim and system and research deeply enough into their own subject, they will eventually discover how they interact and are interdependent, fellow workers in a common field."

Clear Thinking and General Science can both be seen as inventions of the thirties which provided a diplomatic solution to the same problem of the technical fragmentation of the liberal curriculum posed by the growth of knowledge in the sciences - physical, biological and social. The textbooks and new courses of Clear Thinking and General Science were to provide the common ground by which traditional values and shared knowledge would survive, and education would appear to retain its essential coherence and relevance to life: intellectual life, that is. From this perspective, these new texts had first to provide institutional solutions to the problems of conceiving and intellectually reorganising the labour, including the thinking of others, into traditional forms of school knowledge.

Whilst pointing to the philosophical error of advancing this or that subject as the true co-ordinator or integrator, embracing the whole, Jepson and Stebbing nevertheless advanced just this claim for logic. In particular, they portrayed scientific achievement as contructions or architectural logic. They fused moral and intellectual authority in their image of the scientific method - not in the scientific imagination but in their neutral image of technical reasoning.

Between 1948 and 1968, Jepson appeared amongst the recommended texts. The Handbook description of Clear Thinking for the Matriculation English Expression Course was brief and cautiously "taken from the textbooks recommended".

How judgements are made: induction
How judgements are tested: deduction
Scientific method
Definitions
Some common fallacies
Prejudice
The methods of propoganda
The popular press propaganda.

In a reference favourable to Thouless's radical teaching method, the only other directive offered was that:

> "teachers are asked to relate it to the student's environment - to newspapers, popular fiction, advertisements and current films and wireless programmes,"

Jepson's early experience in the thirties with mixed classes of adolescents from both science and humanities allowed him in his early edition to warn of one major teaching problem that was to persist. "In emphasising the negatively critical and destructive side of reasoning there is a danger that the positive contribution of constructive reasoning might be lost sight of". The science students were prone to intellectual vandalism. In later editions he attempted to distance clear thinking from scientific method. In the 1948 edition, "The Scientific Method" was replaced by "What is Thinking?" in which he said he analysed what might be called a unit of constructive thought, with the stated aim of demonstrating not only that clear thinking is a necessary preliminary to creative thinking, but also that the basic method is common to all "subjects". This unit of constructive thought, had the aim of demonstrating, he said, not only that clear thinking was a necessary preliminary to creative thinking, but also that the basic methods were common to all "subjects". "Clear thinking," he urged, in the spirit of social reconstruction, "should be made a means of correlating and integrating the school curriculum on the logical plane". Similar hopes had been held but not realised in the war years by Lauwerys and Turner for General Science in relation not only to separate sciences, but to science and society. "No opportunity," Jepson continued, "should be neglected to show pupils that all knowledge is one, that the common aim of it is the furtherance of human welfare, and that clear and purposeful thinking is a common instrument of that aim." That too was the spirit of science in education, as its earlier proponents saw it, offering in the service of mankind the training to combat "irrational influences."

The first Australian text in this field was written by the Professor of Philosphy, Boyce Gibson, a logician and popular liberal figure in the University of Melbourne; and a well known private school master and literary critic, A.A. Phillips. It first appeared in 1940. The title, Thinkers at Work, like Melbourne Boys' High School motto: "Honour the Work," conveys the importance of an industrious intellect in training for the intellectual disciplines which was seen as intrinsically independent and democratic. In the fifties, Gibson and Phillips were still being impressed by the potential value of Clear Thinking as a logical training and exercise, following the impressive earlier model of Stebbing. There was no section on the scientific method: the treatment was much more literary. The only extended treatment given to scientific reasoning was to a medical example. The authors argued against concentrating on sharpening critical analysis on the writing of others in favour of practising the "game of thought". Whilst less of the formal text in logic than Stebbing, Thinkers at Work is more like Jepson than Thouless in the safe examples it employs drawn from the literacy and philosphical world of its authors. They stated at the outset that they were leaving "such direct social applications as the use and abuse of newspapers, advertisements and propaganda to the cut and thrust of classroom discussion." The Australian teacher was offered little exercises, after the style of mathematics or science texts, in practical logic.

Ideals Corrupted & Reborn in the Sixties

Eric Ashby in the war years pointed to the debasement of science and the scientific imagination in schools and universities to a set of essential definitions and rules to be formally manipulated for examination purposes. A similar corruption of early hopes for Clear Thinking produced similar dogmatic pedantry.

The inventors of General Science and Clear Thinking in England and Australia argued that their reforming purpose was liberal in the sense of countering the alienation of schooling from political life in a democracy. In the Cold War climate of the postwar years, established authority in the form of disciplinary training was reasserted; this time in the service international economic competition. It was not until the sixties that democratic arguments for the principles and methods of education for life were heard again. With the rise in economic and social confidence in the sixties, the public educators were again able briefly to argue for a redefinition of the place of science in liberal education. They sought again to accommodate popular demands, this time using American curriculum models which proclaimed the imperfect panacea of self-fulfilment and social justice through education.

Almost twenty years after the introduction of Clear Thinking, a public reassessment of the methods and purposes of its teaching was attempted by A.C. Jackson and others for the English Subject Committee of the Schools Board in radio broadcasts and in a Circular to Schools. Jackson argued that Clear Thinking ought to imply more than the standard criticsm that insufficient data was presented to draw any logical inferences. It was to be distinguished from the game of cantankerous hole-picking from the thirty-four varieties of logical fallacy listed in one of the major texts, "of throwing these labels such as 'begging the question', 'argument by analogy', 'argument from some to all', 'emotive language', around as though they were hoopla rings occasionally falling over an article." From Jackson's discussion of sample answers, it is clear that many students expressed themselves not so much in prose, but in points, and perhaps worse from the Committee's viewpoint indicated little or no "healthy respect for the difficulties and the power of sustained argument." The attitude that they had hoped to establish in teachers was that Clear Thinking required a technique from students "as advanced common sense." The teaching challenge, Jackson recognised, was to treat hot topics at low temperature in the classroom. Gwen Dow's Uncommon Common Sense published in 1962, the product of her experimental teaching at MacRobertson Girls' High School, became the new text.

As we noted, "common sense" had been invoked before by Thouless and Jepson in defining Clear Thinking in the thirties, but their common sense was associated with a scientific method. Gwen Dow's common sense, however, set out more explicitly to develop the "delicate skills of passing judgement". In questioning the intellectual value of explicit definitions, rules and principles in guiding student thinking, she made explicit a point often made by Turner about the value of delayed specialisation in science training. Dow wrote:

> "One may question whether or not it is wise or feasible to 'teach' clear-thinking concepts explicitly. Experience in trying to teach formal logic (even very elementary, introductory logic) convinced me that this was certainly not the answer at secondary school. At best it tended to produce slickeness and at worst pitiable confusion. Moreover, there seemed no evidence into logic, or consistency, let alone clarity, in the students' own speech and writing. Yet older students *could* I knew, detect different views of history in the books they read and even *in* what they expressed themselves; they could see tht one way of going about drawing conclusions was scientific and another was not, and they could distinguish between when it was and was not appropriate to look for a scientific exposition; they *could* see the value of fantasy, the merits of realism and the brilliant artistic reconstruction of experience in a novel or a poem; they could be funny and serious and know when either was out of place.

There seemed from the sixties to be a place for deliberate self-consious enquiry into such matters: "a conscious effort to lead students to reflect on their own as well as others' efforts." There also seemed to be a place for the scientific imagination and not merely scientific method; but in English Expression rather than Science courses.

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PRESERVICE TEACHERS: PROCESS SKILL ENTRY BEHAVIOUR AND OPINIONS ABOUT TEACHING PRIMARY SCIENCE

Keith Skamp

INTRODUCTION

It has been suggested that a criterion for exemplary inquiry oriented science programs be that they "include teachers who value inquiry, encourage such an orientation, and possess such skills themselves" (Penick and Yager, 1983, p. 623). This paper addresses two questions related to the development of such teachers viz., Do students entering a preservice primary teacher education programme

1. possess competency in science process skills, and have a scientific appreciation of their characteristics and uses; and
2. value inquiry as a teaching strategy, and perceive it as a key purpose in teaching primary science.

The first question is of particular interest in that Scharmann et al. (1986) have suggested that competency in using process skills does not necessarily imply an understanding of the scientific framework within which such skills are imbedded. The relationship between their measure of the latter and student's process skills achievement was therefore explored.

The second question was prompted by Appleton's (1983) conclusion that beginning preservice teachers held strong positive views about inquiry oriented primary science compared to teacher directed product oriented science. It was considered that his result could have been influenced by the use of a structured instrument. Consequently his opinionnaire was readministered, but after the students responded to a more open questionnnaire related to conceptions of the purposes of teaching primary science. The results from the two instruments were compared.

Also responses to both questions will provide baseline data for much needed longitudinal studies of preservice science programmes (Tisher, 1986), and will indicate possible changes in emphases in curriculum content and implementation in such courses.

PROCEDURE

All beginning students in the Bachelor of Education (Primary) degree at the Northern Rivers College of Advanced Education were surveyed and tested during the first week of lectures. Their conceptions of the purposes of teaching primary science were obtained by using an open-ended questionnaire (Zeitler, 1984). Opinions about primary science teaching strategies were determined with Appleton's (1983) structured opinionnaire. Process skill competency and orientation were found using the Test of Integrated processes (TIPS) (Dillashaw and Okey, 1980) and the Process Orientation Towards Science Scale (POTSS) (Sharmann et al., 1986).

The sample sizes for each instrument varied depending upon the response rate and attendance during the first week of lectures. The general characteristics of the student intake are shown in Table 1. Of those students studying one science subject to higher school certificate (HSC) or equivalent level 71% had studied biology. The figures also indicate 26% of all preservice primary teachers had not completed a science subject at HSC level. As is common in preservice primary programmes, males are underrepresentated (here 24%). Mature age students comprise 20% of the sample.

TABLE 1.
BACKGROUND CHARCTERISTICS: STUDENT COHORT

	MALE				FEMALE			
AGE	< HSC Science	One HSC Science Subject	Two HSC Science Subjects	Total	< HSC Science	One HSC Science Subject	Two HSC Science Subjects	Total
School Leavers	3	14	4	21	23	60	9	92
Mature Age	2	8	3	13	8	6	1	15

Key: HSC = Higher School Certificate or equivalent

RESULTS

Process skill achievement

As a cohort the student's mean score on the TIPS test was 25.56 (total number of items was 36). The range was 17 (16 to 33) with a standard deviation (S.D.) of 3.80 (n = 125). These scores compared favourably with Dillashaw and Okey's (1980) results in which a sample of American year 11 students had a mean score of 22.29 (S.D. 8.08.) Other studies using the same (Strawitz and Malone, 1987) or similar (Tobin and Garnett, 1984) tests report higher mean scores for preservice primary teachers after process skill instruction.

An error analysis of the TIPS test revealed the following deficiencies for the stated processes: identifying variables (32.7% incorrect responses); identifying and stating hypotheses (28.4); graphing and interpreting data (25.0); designing investigations (23.7); and defining operationally (22.6).

Tobin and Garnett (1984) have subdivided the steps of 'investigation planning' and 'data processing' into their component parts. Several of these parts are represented in the TIPS test. Further analysis of the current data highlighted the following "investigation planning" items with which the beginning preservice teachers had the most difficulty: identifying the variables to be held constant (50.5% incorrect responses); identifying the variable to be manipulated (41.1); identifying the dependent variable in an investigation (26.6); and identifying variables that may affect the dependent variable (12.3). Tobin and Garnett (1984) reported a similar ranking of item difficulty, although the level of achievement (about 80-90% success rate) was much higher [note: their test was administered after instruction]. Their lowest reported component skill achievement rates (about 60%) were for identifying procedures for holding variables constant, predicting from data presented graphically and identifying procedures for measuring the dependent variable. Only the last mentioned was measured in the TIPS test, with an 80% success rate in the current study.

Analysis of variance indicated significant differences ($p < 0.05$) between male (mean TIPS score 27.37, n = 30) and female students (25.00; n = 95), and between students who had studied more than one science subject beyond year 10 (mean TIPS score, 27.53 [S.D. 3.09; n = 17]), and those who had not completed any science subjects beyond year 10 (mean TIPS score, 24.41 [S.D. 4.63; n = 32]). No such differences were detected between students who had completed only one science subject at year 12 (HSC) level. Similar ANOVA analyses showed age (mature age versus school leavers) was not a significant variable in contributing to the TIPS scores.

Further investigation of the influence of sex and secondary science background via a 2-way ANOVA (with TIPS scores as the dependent variable) resulted in no significant main or interaction effects (although secondary science background was significant at the 0.06 level). This result complicates the interpretation of the above analyses and suggests that only tentative conclusions are possible. Unfortunately the small size of the male group with no HSC science subjects completed (n = 3), does not create ideal conditions for the 2-way ANOVA analysis.

Process skill orientation

The POTSS instrument purports to measure a construct defined as "the ability to recognise/identify the basic and/or integrated science process skills consistent with their application within and contribution to an emergent understanding of the nature of science" (Scharmann et al., 1986, p. 376). It is argued that preservice primary teachers need to be able to more than simply "recognise" the process skills (as in say the TIPS measure); they should be acquiring a "nascent understanding of the nature of science" (p. 376) as a consequence of process skill instruction. The scale has 25 Likert-type items with a score range from a low process orientation of 25 to a high process orientation of 125. The students in the cohort studied (n = 76) had a slightly positive orientation towards science score (mean 89.01; standard deviation 8.26) with a range of 45 (63-108). Ranked POTSS items with the lowest orientations are listed in Table 2 with their descriptive measures. Those items with mean scores above 3.00 (numbers 21, 16, 22, 13 and 7) suggest that students have a neutral to negative orientation towards some process skills in certain contexts: here it appears to be towards the absoluteness of classification systems (21), the accuracy of measurements (13, 16) and their collection (22) and the tentativeness of physical laws (7).

Although Scharmann et al. (1986) reported a Spearman's "rho" correlation of 0.57 between elementary preservice teachers' letter grades in a course assessing the understanding, recognition and application of the science process skills, a low correlation (Spearman "rho" = 0.23) was found between the current study's TIPS and POTSS scores (n = 73). This could be considered to support the view that tests such as TIPS do not "fully characterise the merits, intentions, and desired outcomes reported throughout the literature for an undergraduate's study of the process skills of science" (Sharmann et al., 1986, p. 366). [No significant differences were found between the POTSS score of the groups with differeing 'secondary science background' and 'sex'.]

Some tentativeness about the interpretation of the instrument as measuring "basic" versus "integrated" process orientations must be maintained. Scharmann et al. (1986) reported a two factor solution using a varimax rotation matrix after Kaiser normalisation;

TABLE 2
RANKED POTSS ITEMS +
(1 = Strongly Disagree, 3 = uncertain, 5 = Strongly Agree)

No.		Mean (*reversed)	Standard Deviation	Frequency (%) 1	2	3	4	5
2	Scientific observations are only valid when the results closely match observations obtained from previous experimental research	2.36	0.99	20	41	25	13	1
6	If scientists repeatedly observe that condition A is followed by state B, they can infer that State B will probably occur whenever they observe condition A.	2.43*	0.91	1	16	16	57	9
10	Scientific experiments always follow the same approved five-step procedure.	2.50	0.96	13	41	32	12	3
14	Observations and descriptions derived purely from numerical measurements are superior to observations and descriptions derived purely from verbal expressions and interpretations.	2.62	0.92	6	45	33	12	4
15	A scientist should vary many factors simultaneously in an experiment to obtain faster results.	2.64	1.16	21	25	25	26	3
3	When a prediction comes true, a scientist has successfully proven his/her hypothesis to the exclusion of other hypotheses.	2.78	1.23	15	39	13	28	8
21	Scientists have shown that systems of classifications are operationally well defined because they are, in fact, innate to the physical universe.	3.04	0.58	1	9	75	13	1
16	Scientists look upon the existence of measurement error as unavoidable	3.07*	0.93	4	29	42	20	5
22	In order to compare the soil temperature of 10 potted plants, a scientist should use 10 different thermometers in order to record the data simultaneously.	3.21	1.32	15	18	15	37	16
13	By using appropriate equipment and mathematical relationships, scientists are able to accurately and absolutely determine any object's mass on Earth.	3.22	0.95	5	11	46	29	8
7	A scientific hypothesis may have to be altered on the basis of newly discovered information, but a physical law is permanent.	3.63	0.98	3	9	29	41	18

+ Items are ranked in the order of determined high to low process orientation and those items beneath the line suggest a negative orientation.

however seven of the items did not possess a sufficiently high factor loading (>= 0.30), which leaves doubt about their wording or some other variable. A principal components analysis of the current data yields a nine factor solution (orthogonal transformation-varimax), with between 9 and 16 percent of the total variance attributed to each factor. The variation between the two factor analyses could be due to the highly heterogeneous nature of the entry students compared to Scharmann's sample (see Note 1).

Conceptions of the purposes of teaching primary science

Guided by the classification of 'purposes' used by Zeitler (1984) [Note 2] the list emerged as shown in Table 3. Zeitler's study involved preservice elementary school teachers (well into their training but prior to their practicum).

TABLE 3

Summary Of Purposes Listed By Preservice Teachers

PURPOSE	FREQUENCY N	LISTED %
Teaching science information	107	75
Preparation for future science courses	53	37
Developing an awareness of the world	31	22
Developing student curiosity	25	18
To do and/or learn through practical experiences/ experiments	23	16
Teaching the benefits of science to society	16	11
Encourage thinking and problem solving	16	11
To develop an interest in science	15	10
To encourage children to discover/find out things for themselves	14	10
Part of a general education	14	10
To teach process skills	11	8
To be introduced to/understand what is science	11	8
To encourage environmental concern	8	6
A change from the 3Rs	7	5
To provide an opportunity to co-operate/participate in tasks	5	4
Miscellaneous	16	11
TOTAL / N	372 / 142	
Mean number of purposes listed	2.62	

Despite the differences in the stage of preparation of the preservice teachers there are certain similarities between the two studies. These include 'teaching science information' as the most commonly stated purpose; 'developing an awareness of the world' as an often stated purpose; and the listing of many analogous 'purposes', including 'teaching science processes', (although with a low frequency).

Neophyte preservice teachers place significant emphasis on the preparation of students for secondary science, and if the 'purposes' classified as 'to do and/or learn through practical experiences/experiments'; 'encourage thinking and problem solving'; and 'to encourage children to discover/find out things for themselves' are combined under the general heading of 'teaching problem solving' (37% of responses listed), then it would appear that a small but significant group of preservice teachers (up to one third) do perceive science in the primary school as encouraging more than simply knowledge outcomes.

Three quarters of the sample cited 'teaching science information' as a purpose, and 49% (N = 52) of all respondents who selected their 'most important purpose' chose this category. It was considered, by far, to be the 'most important' purpose [followed by 'preparation for future science courses (14%); 'developing an awareness of the environment' (11%); and developing curiosity (9%)].

Opinions about teaching primary science

Appleton's (1983) opinionnaire claimed to identify views of beginning preservice teachers about various teaching strategies in primary science. His conclusion that beginning student teachers have already formed views about teaching primary science consistent with an investigative emphasis was strongly reinforced in this study.

That the current cohort of students ranked 'pupil experimentation' and 'children learn process skills' items on Appleton's opinionnaire very highly but listed related 'purposes' infrequently in the open-ended questionnaire raises problems about interpretation. This is especially as 'teaching science information' was the most commonly cited (and rated 'most important') 'purpose', but 'children learn concepts' and 'children learn facts' were ranked only moderately or lowly on the structured questionnaire (albeit with means 3.3 or above, which still suggests that a certain degree of emphasis is placed on the item). It is not unreasonable to hypothesise that the structured opinionnaire may be responsible for the responses obtained, and that the open-ended questionnaire (administered first) is a more valid reflection of the emphases neophyte preservice teachers hold about primary science. An alternative interpretation could be that many preservice students may consider using 'process oriented' teaching strategies but with the purpose of children learning science information. [That such teaching strategies could assist the development of science process skills does not appear to be considered a 'purpose' at this stage.]

DISCUSSION

Purposes for teaching primary science

Harlen (1985) has argued that four 'purposes' for teaching primary science can be substantiated from research findings. These are that primary science can (i) make a contribution to children's understanding of the world around them; (ii) develop ways of finding out, checking ideas and using evidence; (iii) build up ideas that will help rather than hinder later learning in science; and (iv) engender more positive and thoughtful attitudes towards science as a human activity. Harlen qualifies the meaning of these reasons but it is reasonably clear that this cohort of neophyte preservice teachers undervalue (iv) especially, and to a large extent (ii). Their emphasis on teaching the 'how and why of things' and primary science as a preparation for secondary schooling could be used to advantage provided that the 'constructionist' view of pupil learning is highlighted in preservice units, and the relationship between process skill development [(ii)] and the achievement of the other purposes is stressed.

That this cohort of students ranked highly items relating to a process orientation towards science on Appleton's (1983) questionnaire, suggests they are "open" to an 'investigative' teaching emphasis. However a consciousness that knowledge acquisition (transfer of information) could override this openness needs to be countered.

Process skills competency and orientation

The ability of future teachers to place stress on pupil 'investigation planning' and 'data processing' (Tobin and Garnett, 1984) will in part be dependent upon their process skill competency. Entry behaviour on the TIPS test indicates a higher achievement level is required, as the results show that a large proportion of students cannot achieve objectives that are typical of those taught in primary school. Tobin and Garnett (1984) and Strawitz and Malone (1987) indicate improvements are possible through preservice education. The former study still expresses concern about mastery levels after instruction. That they found a significant correlation between formal reasoning ability scores and process skill achievement may partially explain this finding. The latter article reports that science process skill acquisition can be enhanced by supplementing teacher instuction in a science methods course with self-instructional science process materials. The TIPS II (Burns et al., 1983) post measures were 27.36 (teacher-instructed) and 32.64 (self instructed).

The possibly significant difference found between (mean TIPS scores) of students studying two science subjects for the HSC and those who completed only year 10 (SC) science tends to support Tobin and Garnett's (1984, p. 94) conclusion that "students with a background in physical sciences are likely to have high level of reasoning ability". A physical science was included among the two HSC subjects by all students with such a background. As Tobin and Garnett's (1984) data suggests this difference may persist after preservice instruction then the 40 percent of (predominantly female) students with minimal secondary science background in this sample who scored very low TIPS scores will need to be closely monitored to determine if remediation is required.

Ability to use science processes does not necessarily imply that students understand the science context within which the processes are imbedded. To be able to measure for example does not mean that an understanding of the errors associated with measurement is understood. When teachers are encouraging children to devise, carry out and interpret investigations their 'orientation' towards the use of the science processes will probably influence the attitudes young children develop towards science [Harlen (1985, p. 160) has remarked: "they (attitudes) cannot be taught . . . they are 'caught', for they exist in the way people behave and are transferred to children by a mixture of example and selective approval of behaviour that reflects the attitude".] Scores on the POTSS opinionnaire suggest that in several areas it would be preferable for the preservice students to change their views. Apart from those neutral to negative orientations mentioned earlier (see page 79) several other items display an uncertainty by the sample group. For example item 10 shows that 47% of the respondents were uncertain or agreed that scientific experiments followed an approved five-step procedure. The POTSS instrument specifies the attitudinal areas needing attention, and as no correlation was found between the TIPS and POTSS scores, science educators need to be especially conscious of making preservice teachers aware of the assumptions behind the use of the process skills. This could be done by self example, workshop and lecture-discussion and is supported by Scharmann et al.'s (1986) report that indicated students' process orientations became more positive depending on the extent of exposure to science courses that included content related to the nature of science.

CONCLUSIONS

This group of preservice teachers entered their education programme with conceptions about teaching primary science which are biased towards science content and preparation for secondary science. However, although process skills are not mentioned specifically by the vast majority of students, about a third of the intake considered "problem solving/discovering" things to be a purpose for teaching primary science. There would appear to be a 'base' for change towards a balanced process-product so favourably to the structured questionnaire on choice of teaching strategies tends to support this opinion.

Process skill competency and orientation must be addressed in the preservice science units but with an appropriate emphasis on their interdependence with concept development. Some input ensuring an understanding of the processes within the overall scientific framework would seem to be required.

The next stage of this study will be to compare the pre- and post-unit data to determine a measure of the changes (if any) that have occurred. As the unit focusses on student led discussions related to the interdependence of science process skill and concept development [Harlen (1985), Chapters 1 to 7]; includes practical investigations which emphasise learner preconceptions and investigation planning, data collecting and processing; and requires students to prepare lesson sequences revolving around Harlen's "shapes", e.g. hypothesis generation (p.p. 166-172), then significant changes are anticipated.

FOOTNOTES

1. SCHARMANN, L.D. (1987). Personal Communication. The POTSS instrument has recently received support for the validity of the conceptual framework under which it was developed. See TAMIR, P., Investigations in Science Education, ERIC Clearinghouse (Ohio State), to be published.

2. Typical examples of 'purpose' descriptors may be obtained from the author. An emergent category classification approach was used. There was often a close similarity in the wording of responses.

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Research In Science Education, 1987, 17, 87-93.

STUDENT BELIEFS AND COGNITIVE STRUCTURE

Colin Gauld

THE LANGUAGE OF ALTERNATIVE FRAMEWORKS RESEARCH

Extensive research into pupils' alternative frameworks has produced many words which are used to describe the various mental entities of interest in such research. A survey of the literature provided a list of basic terms (and commonly associated qualifiers) which are often used interchangeably and these are shown in Box 1.

Within this abundance of terminology a number of concerns are being expressed often without clear explication by the authors.

a) The first and most obvious is that the entities of interest are mental ones and this is conveyed by words like 'thoughts', 'ideas', 'notions', 'concepts', or 'conceptions'.

b) A cognitive emphasis (rather than, for example, an affective one) is conveyed by the use of words such as 'cognitive' or 'conceptual' to qualify other terms used.

c) The label 'personal constructs' emphasises the view that these entities are actively generated in the mind by the learner rather than simply assimilated in the same form in which they were presented (for example, by the teacher).

d) The terms 'structures', 'frameworks' or 'systems' refer to the idea that the particular mental entities of interest are organised into broad, interlocked, coherent networks rather than existing as independent units. This is in contrast to the smaller scale entities designated by words such as 'concept', 'idea', or 'notion'.

e) Words such as 'knowledge', 'understanding' and 'science' are often used to focus attention on the claim that these frameworks or systems are held in a rational manner, that is, that those possessing them do so for good reasons.

BOX 1

A summary of common terms used to lable mental entitles in research into pupils' alternative frameworks.

QUALIFIER	BASIC TERM	QUALIFIER
	thoughts	
	ideas	
	notions	
	concepts	
	intuitions	
	perceptions	
	cognitions	
	opinions	
	interpretations	
	meanings	
	schemata	
pre-, mis- alternative	conceptions	
alternative	views viewpoints	
personal	explanations constructs	
personal conceptual	understandings	
alternative conceptual	frameworks	
cognitive knowledge	structures	
cognitive intuitive	systems	
commonsense conceptual intuitive personal private public	knowledge	
intuitive	beliefs commitments	
children's teacher's scientist's	science	
mini -	theories	-in-action

f) The fact that the ideas or frameworks are possessed in such a way that they strongly influence the behaviour of the individual is expressed most clearly in words like 'beliefs', 'commitments', 'perceptions', or 'intuitions'.

g) The claim that individuals make sense of their limited experience in a similar way to that which scientists use and that frameworks function like scientific theories is expressed through use of the term 'theories' and qualifiers such as 'alternative' (frameworks, conceptions, or views), 'mis-' or 'pre-' (conceptions), 'children's' (science), and 'personal', 'private', 'commonsense' or 'intuitive' (knowledge).

The above list identifies a number of dimensions for those mental entities of interest to research workers in this field. Two of these, to be discussed further, are:

A. the extent of commitment to the ideas contained within the system, and

B. the rationality or coherence of the system of concepts.

THE EXTENT OF COMMITMENT TO MENTAL ENTITIES

The word 'belief' is used here in the sense of an idea to which its possessor is committed and which, as a consequence, influences relevant courses of action. Beliefs may be thought of as ideas which have a strong affective component and they are totally compatible with Allport's widely adopted definition of an attitude as:

> a mental and neural state of readiness, organised through experiences, exerting a directive or dynamic influence upon the individual's response to all objects and situations with which it is related. (Allport, 1967, p.810)

Driver (for example, 1983) most consistently refers to alternative frameworks as beliefs and explicitly emphasises their role in establishing expectations which then help to determine responses in relevant contexts.

One of the values of characterising children's frameworks as beliefs (or systems of beliefs) is that it allows attention to be focused on those things which a pupil 'knows' or understands but does not believe. A pupil may be able to give an outline of what he or she considers to be the teacher's (or another pupil's) view on a particular matter while, at the same time, rejecting that view. The pupil may possess an elaborate conception of the teacher's position, be able to make inferences from it and yet not adopt it as his or her own view. Alternatively, the pupil may have developed an idea in order to test it further and so may possess a conception which, at the present time, does not function as a belief in the way it might if it survives the period of testing. For want of a better term these tentative or rejected ideas are called here 'alternative understandings'.

Schutz and Luckmann (1974, pp. 154-169; Luckmann 1983) in their discussion of the structure of the subjective stock of knowledge, suggest that such items of 'knowledge' can be characterised by their degreee of credibility. This takes into account the fact that some concepts are rather firmly entrenched and frequently influence action, others exist in the stock of knowledge in a much more tentative, loosely integrated (but no less elaborate) manner, while others possess negative credibility and are rejected.

Thus a person's cognitive structure not only contains beliefs but also alternative understandings and Posner and his colleagues (Posner et al., 1982; Strike & Posner, 1982) have pointed out the importance of intelligible alternatives to one's present position if conceptual change is to occur. Crucial to their conception of conceptual change as a rational process is the possession of ideas to which the person is not yet committed but which are potential competitors and which require some degree of understanding before being adopted or rejected.

THE RATIONALITY OF MENTAL ENTITIES

Beliefs

A distinction is often made in the philosophical literature between 'mere belief' for which little justification is provided ("I don't know why - I just believe it"), beliefs which are based on evidence and reason ("I believe because . . . "), and beliefs, based on evidence and reasons, but which also happen to be true (or at least founded on criteria accredited by experts). The word 'belief' is often reserved for the first of the above categories while the word 'knowledge' is frequently reserved for the last (Martin 1972, pp. 133-137). However, all three types of belief probably function in mental activity in much the same way and the word will be used here in the broad sense outlined above. In a similar manner, the alternative understandings a person possesses but does not adopt may be rejected with little justification or with varying degrees of reference to evidence and reasons.

Terms such as 'alternative frameworks', which are frequently used to label these beliefs are chosen to acknowledge the validity or rationality which the ideas possess. The notion of 'children's science' suggests that students make sense of their limited experience in a similar way to that which scientists use to make sense of their more extensive data. The word 'misconception' indicates that the notion differs from what is generally accepted (for example, by teachers or scientists) as the best view, but it also implies that the pupils have mistakenly arrived at their ideas. However, many people reject it as an appropriate label where the basic source of the belief is in a more limited range of data rather than in faulty thinking.

Reasons

Another important component of the rational side of a pupil's cognitive structure is the network of reasons to which the pupil appeals in order to justify the belief which has been adopted and to reject other available alternatives. Where reasons are available they may include appropriate (or inappropriate) reference to empirical evidence, to other beliefs or preferences, to the concurrence of experts (such as teachers), to the views of other members of the class, to epistemological and metaphysical commitments, and so on and judgements by external observers about the rationality of a position will often be made on the basis of the perceived adequacy of the reasons which are offered.

In some cases the student may not be able to give reasons for the present position or be able to recall information which supports the view. For the pupil it may just be obvious that this is the only way to view the world. In this latter case the belief has been detached from the specific events which gave rise to it and has been "sedimented" into the stock of everyday knowledge (Schutz & Luckmann 1974, pp. 199 ff; Luckmann 1983).

In spite of the fact that children may not always be able to give adequate reasons for their beliefs an outside observer who studies the conceptions which a child adopts is often able to makes sense of the particular view in the light of experiences assumed to have been encountered by the child and hence may argue that the belief is a reasonable one for the child to hold. For example, the widespread adherence to the view that a resultant force acts even in the case of an object moving with constant velocity is considered to be reasonable because real objects do stop (due to the effect of friction) when all the other forces are removed. In this sense the child's view can be considered to be rational from the perspective of the observer even though the child may not be able to adequately support the position adopted.

In the model of conceptual change proposed by Posner and his colleagues the intelligible alternative must also be plausible, that is, there must be good reasons (from the point of view of the learner) why the notion should at least be given further consideration.

DISCUSSION

Alternative frameworks research has largely been carried out in three areas - identification of pre-instructional beliefs, design of instructional strategies for altering student beliefs, and identification of post-instructional beliefs. Most of the proposed instructional strategies include stages where students become aware of alternative points of view to their own, where they argue the case why their beliefs should be accepted, and where they are confronted with empirical evidence which supports the scientific viewpoint (Cosgrove & Osborne, 1985). However, in the pre- and post-instructional phases of the research, attention is almost exclusively focused on student beliefs and how these have altered. Little interest is shown in the alternative understandings students possess (especially before instruction) or in the reasons they appeal to in order to justify their position. While pupils are often asked to give reasons as part of investigations into their belief systems or alternative frameworks these requests usually seek to clarify the nature of the student's belief by asking, for example, why a certain prediction is made rather than being a request for reasons for adopting the belief in the first place.

In addition, little work has been carried out to determine how students, who obviously appreciate the significance of empirical evidence supporting the scientific view, justify the adoption of other notions than orthodox ones. A recent study (Gauld, 1985, 1986) has demonstrated that even when a student maintains a particular unorthodox belief throughout a specially designed series of lessons the cognitive context in which this belief is embedded can radically alter as a result of the instructional strategies employed.

In research into pupils' alternative frameworks it is important to establish not only the beliefs which claim an individual's commitment but also the wider setting of alternative understandings and reasons which help to provide some foundation for such beliefs within the pupil's cognitive structure.

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SOCIAL BACKGROUND, SOURCES OF INFORMATION, MODELS OF BEHAVIOUR, ATTITUDE, AWARENESS AND BEHAVIOUR IN HEALTH-RELATED MATTERS

Max Maddock

BACKGROUND

The 1980 N.S.W. Junior Secondary Science Syllabus objectives (Secondary Schools Board, 1980) require the teaching of body systems, conditions for proper functioning of body systems, the effects of stress, drugs, pollutants and nutritition, in order to achieve appropriate attitudes "so that wise decisions can be made in relation to the development of sound health practices".

In specialized health curricula, there is also a belief that the programmes can develop knowledge, attitudes and behaviour. For example, The Queensland Health Education Curriculum Guide Grades 1-7 has a set of main ideas promoting knowledge, attitudes, values and behaviour essential to individual, family and community health. The Western Australian Health Education Advisory Committee contends that a large number of health problems are a consequence of patterns of behaviour and attitudes developed while young and that these "patterns of behaviour, beliefs and attitudes can be influenced by a healthy school environment" (Health Education Advisory Committee, 1981).

Numerous studies investigating attitude-information relationship have indicated little relationship between provision of information, attitudes and behaviour, with regard to health, particularly in the smoking-alcohol domain. For example, an Iverson and Portnoy (1977) review concluded that health education programmes have demonstrated ability to increase level of knowledge and to foster positive health attitudes, but that these were not factors in adoption of satisfactory health behaviour. Petosa (1984, p.22) stated: "The failure of health knowledge acquisition to promote health lifestyles is one of the best documented dilemmas in the fields of health education".

Murray (1984) stated that most health education efforts prior to the 1970's were largely knowledge orientated, but little hard evidence exists on its effectiveness as a deterent to smoking. More effective programmes have to rely on balancing internal (attitudinal) and external (social normative) factors, with both dimensions being interdependent (Green, 1970).

Social factors such as family attitudes and peer pressure appear to be potent ones. For example, Nolte, Smith and O'Rourke (1983) found parental attitude even more strongly associated with the smoking of children than parental behaviour, while Sunseri et.al. (1983) found family involvement necessary to affect attitudes and behaviours, and peer influence and self-esteem also related to smoking knowledge, attitude, future intentions and the purchase of cigarettes.

Craft and James (1984) point to the uphill struggle facing school health education, highlighting the still predominant tendency to retain a narrow subject sense, as indicated in the New South Wales syllabus referred to earlier (Secondary Schools Board, 1980), and the importance of situational variables such as family structure, cultural traditions, economic and social factors and commerical pressures.

French (1984) stated that the school situation cannot be separated from its social, community and family contexts. It has been demonstrated that the types of beliefs that distinguish smokers from non-smokers are social rather than those related to health consequences (Peers and Christie, 1984).

This study was designed to investigate awareness, attitude and behaviour in health-related matters in the context of personal and social beckground factors. It was funded by Menzies Foundation Grant.

Methodology

During 1983 a common questionnaire, focussing on background variables, linked with two other questionnaires randomly chosen from the Community and Personal Health Attitude Scale (CPH), the Health Awareness Scale (HA) and a Health Behaviour Scale (HB) were administered to 10 high schools in the Hunter Valley in N.S.W., 3 high schools in Melbourne, and 3 high schools and 3 matriculation colleges in Tasmania. Sample sizes were 947 for CPH, 895 for HA and 1394 for HB, with a total of over 1500 subjects. The random pairing technique was adopted so that large samples of attitude, awareness and behaviour responses could be obtained.

The CPH scale was a 22 item questionnaire measuring attitude to community and personal health. The HA scale was a 26 item scale measuring knowledge of health issues. The Health Behaviour questionnaire consisted of 172 independent items, not designed for summative scoring, on specific aspects of exercises, diet, drug usage, sources of health information, models for health behaviour and family health history.

The results of the investigation by this study into the development of awareness and attitude across grades, the relationship between attitude and awareness, and the overall drug-usage level by the sample have been reported in Maddock (1985).

Sources of Information

Eleven sources of information were acknowledged by 40 percent of more of the high school students sampled as having provided some input into their knowledge of health issues (See Table 1). Of these, science lessons figured in the five most chosen source only for diet, where it ranked fourth, and for disease, where it gained the second highest percentage.

The most chosen source for diet, drugs, disease and alcohol was parents, who were acknowledged by 79 percent or more. Television and magazines ranked in the top three for diet, drugs and alcohol. The newspaper was the fourth most popular choice for drugs and alcohol, with family ranking 5th for diet and alcohol, and third for drugs. Doctor was equal third most popular choice in the case of disease.

Models of Behaviour

Father, Mother, Other Family and Friends came out as the four most supported models for stimulating both similar behaviour and different behaviour, with Sport Personality gaining fifth most popular support as a model for similar behaviour in the case of exercises and diet, and teacher ranking fifth in the case of drugs and alcohol. Although Television had appeared as a popular information source, Television Personality, a Character in a Television Drama and Television Commerical, together with Pop Music Star, received relative minor support.

The strongest acknowledgement was for models stimulating similar behaviour, with less than 30 percent acknowledging models of different behaviour. These were strongest in the case of drugs and alcohol, where both mother and father were attributed as providing models for different behaviour.

Family and Peer Influence

Although family was ranked in the five most popular information sources for diet and alcohol only, and friends was similarly ranked for drugs only, they both attracted more than 50 percent of responses. As models of behaviour, both ranked in the top five. It is clear that the family-peer group structure is a significant underlying factor in developing knowledge, attitude and behaviour in relation to health issues. The findings of this study are consistent with investigations into smoking and alcohol in children e.g. Olsen, Redican and Krus (1980), Sunseri et.al. (1983), Nolte, Smith and O'Rourke (1983), and Higgins, Whitley and Dunn (1984).

Personal and Social Background, Awareness, Attitude and Behaviour

As influences such as the type of magazine literature available in the home, the type of T.V. programmes watched and the characteristics of a peer group in a community or school are closely dependent on home social and cultural factors, cluster analysis using these factors was undertaken. The analysis produced 8 clusters with distinctive profiles, of which the four most contrasting will be discussed here. The profiles of the Clusters are illustrated in Table 3, where variations of 5 percent or more from the overall sample proportions are given as plus or minus figures for a selected number of typical categories. Space precludes giving the complete profiles. The text refers to relative proportions compared with the pattern for the overall sample.

Characteristics of Cluster A

The cluster consisted of 16 percent of the sample. The mean was the highest for attitude (0.19 Standard Deviation above the whole sample mean and 0.52 above the mean of Cluster D) and for awareness (+0.38SD relative to the whole sample mean and 1.09SD above the mean for sample D). The group was characterized by children of professional/business parents, with parents in full or part-time employment. The highest level of education achieved by the parents was more likely to be Technical, University or CAE. The vast majority lived in a two-parent home.

Academically the vast majority considered themselves above average in science and other subjects. They tended to watch less T.V. and listen to less radio. Their habits with the milder and more serious drugs and alcohol were more abstemious. Diet habits were close to the concept of a balanced diet, with fewer consuming fast foods on a regular basis.

Science lessons and parents were perceived as sources of information for diet, drugs and alcohol, but the group pattern did not differ from the overall pattern on Television as an information source. Father provided the model for similar behaviours in the case of drugs, while mother provided a similar model in the case of both drugs and alcohol. However, mother was a "different" model for a significant group in the case of exercise.

Characteristics of Cluster B

Cluster B consisted of only 6 percent of the whole sample, was equally aware of health issues as Cluster A (Mean +0.38 SD), but not significantly different from the whole sample mean or the mean for Cluster C for attitude (+0.09 SD), although significantly more positive (+0.42 SD) than Cluster D.

There were fewer business/professional fathers, but a compensatingly higher percentage of fathers in skilled trade. A somewhat higher proportion of mothers were in full or part-time employment. More than half the mothers were reported having grades 7-10 as their highest level of education. Somewhat more regarded themselves as above average academically in both science and other subjects, compared with the overall sample norm.

The group contained more tobacco smokers, but the percentage of occasionally or more users of marijuana was low and for heroin zero. However, a small but significant proportion claimed to have experimented with sniffing fumes. The figures for occasional or more frequent beer and wine drinkers were higher, but for spirits the figure did not differ significantly from the level in the overall sample.

Science lessons were given credit as a source of information for all of diet, disease, drugs and alcohol and parents were credited as minor information sources for diet, disease and alcohol by more than the norm. Television also featured somewhat more prominently as an information source of diet, disease and alcohol.

Father was rejected as a model of similar behaviour for exercises, and also for drugs, although to a somewhat smaller extent. Mother featured more prominently only for alcohol, as a similar model. Television personality was reported as a stimulating a significant proportion towards different behaviour.

Characteristics of Cluster C

Cluster C consisted of 5 percent of the sample. Attitude was right on the overall sample mean (-0.02 SD), as was the level of awareness (Mean +0.06). Grades 9 and 10 were more predominant, and males were more in the majority than in other clusters.

Business and Professional occupations were significantly less represented for both parents and skilled trades less represented for fathers. Significantly more mothers were engaged in home duties and unemployed or retired/pensioner fathers were in a majority. A significant section of members claimed not to know their parents' level of education. A salient feature was the high proportion of single parents homes. Fewer claimed to be above average academically, with a compensating significant group claiming to be below average. The claimed hours of TV watching and radio listening tended to be higher and the proportion claiming to watch or listen to ABC stations was very significantly higher than the very small (1-2 percent) percentage for the overall sample.

The group was characterized by more people claiming occasional or more frequent use of tobacco, marijuana, heroin, beer, wine and spirits.

School science was acknowledged as a source of information for disease, drugs and alcohol, and parents did not feature any more or less prominently than for the overall sample except of diet, where somewhat more rejected the parental source. However, Television was acknowledged for diet, diesease and drugs.

Parents received a significantly higher rate of rejection as role models for exercise, diet and drugs, whereas the response rate on teachers as a role model did not differ from that of the overall sample.

Characteristics of Cluster D

Cluster D consisted of 5 percent of the sample and was the polar opposite to Cluster A for attitude and awareness, with means -0.52 SD and -1.09 SD respectively, (-0.33 SD and -0.71 SD) respectively compared with the overall sample. Fewer business and professional fathers, fewer mothers on home duties and fewer fathers in full or part-time employment were reported. A higher proportion of fathers and mothers were credited with grades 7-10 as the highest level of education. More group members claimed to be below average academically.

The group was featured by the higher level of claimed use of tobacco, the hard drugs, and all types of alcoholic beverage. Fast food, packaged meals, high salt usage and other less desirable diet habits were a feature of food consumption.

The pattern for science lessons as a source of information was inconsistent, with more claiming no information for diet, and drugs, and more claiming a large amount of information for drugs and alcohol. A wide range of behaviour models was reported, with both Father and Mother featuring as a stimulus for producing different behaviour, indicating a level of home conflict on these issues. Television Personality also tended to evoke a "different" response.

DISCUSSION

The community tends to put great pressure of the schools and teachers to achieve a wide range of socially desirable objectives. Developing appropriate knowledge, attitude and behaviour in relation to health matter is one of these pressures. An example of this is the new demand for AIDS education in schools. Research evidence has shown that information-based approaches are relatively ineffective. Previous studies have indicated the importance of peer group and family influences.

This study demonstrates the complex background factors involved in the acquisition of health awareness, attitudes and behaviour, inter-relationship of personal and social factors, sources of available knowledge and the acquisition of attitudes and behaviour. An single focus programme, whether undertaken within the study of school subjects, such as a science, or specially designed health courses, is unlikely to be successful. The characteristic patterns within society need to be analyzed and programmes specially targeted to suit them. It is clear, for instance, that Cluster A and Cluster D, indentified here, would require vastly different programmes.

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TABLE 1

SOURCES OF INFORMATION

	Science Lessons	PD Lessons	Health Lessons	Newspaper	Magazine	TV	Radio	Parents	Family	Doctor	Friends
DIET	71	54	54	55	72	75	50	87	63	61	57
DRUGS	53	60	54	65	66	74	46	79	58	54	61
DISEASE	77	66	58	59	66	71	40	81	59	71	51
ALCOHOL	47	55	51	63	68	72	43	82	58	46	57

TABLE 2

MODELS OF BEHAVIOUR

		Father	Mother	Other Family	Friends	TV Personality	TV Character	Sport Personality	Teacher	Pop Star	TV Commercial
EXERCISE	SIM	55	59	50	57	40	31	49	44	29	33
	DIFF	16	17	11	11	9	7	11	9	8	7
DIET	SIM	56	64	48	46	30	24	37	28	23	31
	DIFF	16	17	12	9	7	7	8	8	8	8
DRUGS	SIM	39	39	36	37	20	21	22	29	19	20
	DIFF	24	27	20	19	11	9	12	17	11	9
ALCOHOL	SIM	44	45	36	44	22	19	23	27	17	19
	DIFF	24	22	15	13	8	7	10	13	9	8

Table 3

Cluster Profiles: Selected Typical Key Categories Only

Values Related to Those of Overall Sample

(Blank columns indicate within 5% of Overall Sample)

Cluster		A	B	C	D	Overall
N		220	81	66	66	1390
% of Sample		16	6	5	5	
Attitude		+0.19SD	+0.09SD	-0.02SD	-0.33SD	0
Awareness		+0.38SD	+0.38SD	+0.06SD	-0.71SD	0
		Percent	Percent	Percent	Percent	Percent
Grades	7-8		+11	-15		44
	9-10		-19	+12		44
	11-12		+8			11
Sex	M		-7	+7		45
	F		+7	-8		55
Fathers' Occupation						
Business/Profession		+16	-9	-22	-5	36
Skilled Trade			+7	-10		24
Mothers' Occupation						
Business/Profession		+16		-8		10
Home Duties		-6		+14	-6	35
Fathers' Employment						
Full/Part-time		+7		-84	-7	90
Unemployed				+49		4
Retired/Pensioner				+36		4
Mothers' Employment						
Full/Part-time		+7	+5			59
Home						
Live One Parent/Guardian				+30		12
Live Both Parents/Guardian		+7		-46		84
Fathers' Ed.	Primary			+8		4
	Grades 7-10	-14		-11	+26	38
	Technical	+10		-6		11
	Uni/CAE	+15		-7	-7	12
	Don't Know	-12		+23	-21	27
Mothers' Ed.	Primary			+8		4
	Grades 7-10	-7	+10	-10	+6	43
	Technical	+6				5
	Uni/CAE	+12				11
	Don't Know	-13		+11		22
Science Results	Above Average	+45	+6	-11	-8	46
	Average	-32	-5			41
	Below Average	-12		+6	+15	13
Other Results	Above Average	+42	+5	-11	-5	53
	Average	-38	-7	+6		43
	Below Average			+6	+10	4
TV Watching	Commercial Only	-8			+8	27
	Mixture ABC/Comm.	+5	+5	-11	-9	69
	ABC Only			+8		1
Hours TV/Day	Less 1 Hour	+8				9
	1-2	+19		-6		35
	3 or more	-25	+6	+6		55
Type Radio	Commercial Only		+6	-7	-5	75
	Mixture ABC/Comm.					20
	ABC Only			+7		2
Hours Radio	Less 1 Hour	+16			-11	56
	3-4	-8	+6			31
	More than 4	-6		+5	+6	13
Drug Usage and Diet						
Tobacco	Never	+10			-5	52
	Once/Twice		+8	-12	-12	12
	Used to/Now Never				+5	6
	Occasionally or More	-11	+8	+7	+14	28
Marijuana	Never	+9	+11	-14	-16	77
	Once/Twice				+6	5
	Used to/Now Never					1
	Occasionally or More		-10	+10	+12	15
Glue/Fumes	Never	+6			-25	83
	Once/Twice				+6	5
	Used to/Now Never					1
	Occasionally or More				+13	6
Heroin	Never	+5	+8	-6	-8	90
	Once/Twice					1
	Used to/Now Never					1
	Occasionally or More		-6	+5	+5	6
Beer	Never	+18	-6	-5	-9	33
	Once/Twice		-7	-5		17
	Used to/Now Never					1
	Occasionally or More	-16	+15	+9	+9	47
Wine	Never	+9	-8			25
	Once/Twice				-8	21
	Used to/Now Never					2
	Occasionally or More	-8	+6	+7	+10	51
Spirits	Never	+11		-11	-8	45
	Once/Twice		+5		-6	17
	Used to/Now Never					1
	Occasionally or More	-7		+6	+16	35
Hamburger/Hot Dog	Never			+6		5
	Less Once/Month				-7	23
	Once/Month	+10		-8	-14	38
	Once/Wk or More	-11		+5	+19	34
Packaged Meals	Never		-10			52
	Less Once/Month		+8		-9	25
	Once/Month					14
	Once/Week or More	-5			+15	9
Salt Added	None	+8	-5		-10	
	Meat/Veg. Only		+9		-8	
	All Food	-6			+13	

Cluster			A	B	C	D	Overall
Sources of Information							
Science Lessons							
Diet		- None	-8	-16		+11	28
		- Small		+17		-8	50
		- Large	+11				21
Disease		- None		-11	-7		23
		- Small		+9			46
		- Large			+6		31
Drugs		- None	-12		-7	+8	46
		- Small	+14	+6		-14	36
		- Large			+6	+8	17
Alcohol		- None	-11	+7		-8	53
		- Small	+9				31
		- Large		-5	+5	+8	16
Parents	Diet	- None			+6		12
		- Small		+9	-6		31
		- Large	+11	-8			56
	Disease	- None					18
		- Small		+15		+5	32
		- Large		-10		-5	49
	Drugs	- None					21
		- Small		+13			36
		- Large	+5	-11			43
	Alcohol	- None	-6			+8	18
		- Small					39
		- Large	+5			-9	43
TV Programmes	Diet	- None	+5	-7	-7		25
		- Small			-7		52
		- Large		+6	+14	+6	23
	Disease	- None		-6			29
		- Small		+7	+5		47
		- Large		-6	-8		24
	Drugs	- None				-7	25
		- Small					47
		- Large			+5	+7	27
	Alcohol	- None		-7		+9	28
		- Small		+13			45
		- Large		-5			27
Models of Behaviour							
Father	**Exercise**	None			+7		30
		Similar		-7	-6	-21	55
		Different				+16	16
	Diet	None		+10			28
		Similar		-9	+6	-14	56
		Different			-10	+13	16
	Drugs	None	-10	+5	+10		38
		Similar	+12		-5	-12	39
		Different			-5	+8	24
	Alcohol	None				-7	33
		Similar				-5	44
		Different				+11	24

Cluster			A	B	C	D	Overall
Mother	**Exercise**	None			+15	-8	24
		Similar	-5		-11		59
		Different	+9			+9	17
	Diet	None				+7	19
		Similar				-8	64
		Different					17
	Drugs	None	-8		+5		35
		Similar	+11			-10	39
		Different			-6	+10	27
	Alcohol	None	-5		+5	-12	33
		Similar	+5	+8	-8		45
		Different				+15	22
T.V. Personality							
	Exercise	None				-18	64
		Similar		-9		-6	30
		Different		+10		+18	7
	Diet	None				-10	64
		Similar					30
		Different				+6	7
	Drugs	None				-14	69
		Similar				+9	20
		Different				+5	11
	Alcohol	None	+6	+5		-20	
		Similar					
		Different				+16	
Teacher	**Exercise**	None				-14	46
		Similar				+14	44
		Different					9
	Diet	None	+8			-12	54
		Similar					38
		Different				+8	8

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GIRLS IN SCIENCE - AN EVALUATION OF ONE SCHOOL'S APPROACH TO THE GENDER BIAS IN SCIENCE

Barbara Johnson, Peter Fensham, Gail Hildebrand, Shirley Sampson

"It's a trial to see if the girls do better."

This is one parent's view of why Scoresby High School has begun the all-girls classes for science in years 9 and 10 in 1987.

The paper by Wood and Franck (1987), outlines the characteristics of the school, the processes that were used to establish the all-girls classes and the actual organisation of the project. This paper explains the processes and strategies being used to test the hypothesis put forward by the parent - Do the girls do better?, - as well as a few comments on the preliminary findings.

In Victoria, as in the wider Australian community and the world there is a lot of comment, even debate about the participation of girls/women in education and employment. More specifically the great concern is the low participation rates of girls in the science-mathematics areas of the school curriculum as well as the low rate of choice, by women, of the science/technological fields of employment.

The concern is so great that a National Policy for Girls will be released soon. The plan of action is a 'comprehensive attempt to ensure girls can participate as fully as boys in all aspects of schooling. It is part of the Commonwealth Government's over all program to improve women's status and participation in society in general.' Senator Susan Ryan, Minister for Education, Press Release May 22, 1987.

Many individuals and groups have been and continue to be interested in the "problem" of girls in education or equal opportunity for all students. Science and Mathematics are the main areas of the school curricula that are researched the most.

The project reported by Wood and Franck (1987), has been established by Scoresby High School as its response to the issue. The evaluation team from Monash has approached the situation as a Case Study and we are endeavouring to gather as much data as is practicable and possible during the life of the project at the school. In particular we are investigating aspects of the issue which have not been covered in other research, namely, the response of parents and their attitude to girls and science compared to their sons, or boys in science; girl's previous involvement in science- apprenticeship type activities compared to boys; teachers' perceptions of single sex/co-ed. classrooms and further down the track, observations of classroom interaction in both types of settings, with the same teacher, same topic.

THE PROCESS

The issue of girls participation in science has many facets. The main 'actors' are TEACHERS, STUDENTS, PARENTS. What role do each of these groups play in the situation of girls in science at Scoresby?

A series of questions to be investigated for each group of 'actors' was developed in order to guide the evaluation process.

Teachers

Are they aware of the gender debate?

What are their views about girls and science?

What views do they have about the intervention strategy being used at Scoresby High School?

What is their teaching style? Is it different for the single-sex class and mixed class?

Students

What are their views about science as a career?

How important is science to them now and in the future?

What effect do peers have on attitudes?

Does the placement in the single-sex class affect attitudes/achievement, subject choice and employment?

Parents

What is their experience in science?

How supportive of their daughters schooling are they?

What views about girls, science and employment do they hold?

What expectations do they have for their children?

School

What is the general atmosphere for girls at Scoresby?

What is the curricula?

What effects does the project have on the school as a whole?

Having identified all these questions for investigation, How? was the next issue. Table 1 shows the details of the evaluation schedule. (see end paper).

It is obvious that the attitudes of the various 'actors' in the project are a major aspect of the data. The measurement of attitudes is a science in itself. Surveys, questionnaires, interview schedules and scales (Likert, Thurstone) have been used by many researchers to record attitudes. Dr. Paul Gardner (1974), from Monash has researched student attitudes to science. Jan Hardy (1983), in the UK., as well as Jane Kahle (1985), in USA., have been concerned about the opportunities for girls in science. In developing the specific questionnaires to record the attitudes of teachers, students and parents the evaluation team drew from the work of previous researchers, including the local study of Single-sex versus mixed classes in mathematics at Ballarat High School (Rowe, Nix & Tepper, 1986) and Hildebrand (M.Ed. Thesis, 1987).

The attitudes of the teachers and students were recorded in Nov. 1986 via a pencil and paper questionnaire using a 5-point Likert scale (strongly agree to strongly disagree). The knowledge of sex differences and attitudes toward sex-role stereotyping were ascertained by using the Scott Sex-role Inventory (SSRI). This 37-item questionnaire was developed by Judith Scott and John Bradley in an attempt to provide an index which might help to assess the need for attitudinal changes and the effectiveness of intervention program. (Scott & Bradley, 1983).

An extensive questionnaire of three parts was completed by all students of years 8 & 9 in November 1986.

Part A - General Information. These questions were about interests in school subjects and employment, what sex-role views did the students have and who influences their decision?

Part B - Attitudes. The 74 questions in this part were selected from a number of scales that had been used by other researchers in the gender debate. A 5-point Likert scale being used. Lowe's (1985), Self-confidence and Success in Science scales; Kahle & al (1985), subscales of Science Career Interest; Extra-curricula Science Activities; Feelings about Science; and Research funding; Erb and Smith (1984), three dimensions of attitudes towards women in science were also included.

Part C - More Attitudes. These were open ended questions. The students were asked to give their opinion for questions such as -

'the best thing about science classes is?', and,

'my favourite school subjects are...'.

All questions on the teacher and student questionnaires have been found to be reliable and valid indicators of knowledge and attitudes in this area.

The parents attitudes towards the project and how they see science as a school subject as well as its role in their daily lives were assessed by an interview. A random sample of 32 families with daughters in year 9 & 10 in 1987 were interviewed using a pre-planned schedule of questions. Each interview was recorded on tape and in writing by the interviewer. The questions were designed to enable some cross referencing to be made to the survey of the students.

Part A - comprised questions to ascertain the parent's perceptions of their daughters attitudes to science.

Part B - the questions posed here were to gather data about the attitude of the parents towards their daughter's science education.

DATA

The information gathered to date gives an outline of the characteristics of the main 'actors' in the project. Let us look at the questions for each group 'actors' separately.

TEACHERS

Awareness of the gender debate.

There are four teachers teaching single-sex classes, two females for year 9 and two males for year 10. Each of these teachers also teaches a mixed class at the same year level. The attitudes of these four teachers is important and they are reported here in Table 1 as scores on the Scott Sex-Role Inventory.

TABLE 1

Shows the attitude scores for the four teachers with all girls classes in 1987.

SCALE	NO. QUEST.	Attitude scores, max. 5 F.1	F.2	M.1	M.2
Knowledge	17	3.7	3.5	3.4	3.5
Attitudes	20	4.7	4.8	3.6	3.9 (6 subscales)

There is no real difference between these four teachers with respect to their knowledge about the sex-role stereotyping that occurs in our society. However, the attitudinal measure indicates a difference of one rating point in favour of the females. This difference is in a positive direction.

Views about girls and science

When asked to describe any differences they perceived between the sexes in respect to aptitude and interest in science both male teachers believe a difference does arise as the students progress through years 7-10, the boys are more interested but the girls get better exam results, whilst the females were a little less precise about any differences. One female teacher believed that boys are more motivated.

Views of single-sex classes

Asked the question 'Would you choose to teach an all-girls class? Why? both female teachers said they did not mind if they taught a single-sex class, whereas the male teachers gave a definite no and indicated that they did not believe that segregation was the answer.

None of the four teachers expected any differences to occur in the classes.

Teaching styles

To date this has not received much attention other than some anecdotal comments from students and parents.

One of the male teachers has not enjoyed the experience of teaching a single-sex class. He has requested and been granted another class for semester two. The first unit of study for this particular teacher was a physical science unit. He felt that girls did not handle the topic at all well. The top mark for one test being 14/22.

STUDENTS

It is a more complex task to sketch the characteristics of these 'actors'.

All students in year 8 & 9 have completed the questionnaire referred to in the process section. There is a wealth of information awaiting statistical analysis. A few of the interesting pointers so far will be mentioned.

Support/Encouragement

The only significant difference obtained was in the area of support from the science teachers. The year 8 students felt that in year 7 their teachers had discouraged them, but the present teachers (1986) were more supportive.

Subject suitability

Of the 23 students available at the school for students in the last two years of schooling it is correct to say that the majority of the subjects are seen by the students as suitable for all students to study. There are several notable exceptions;

1. General Science
   There is a significant gender bias towards suitability for boys as perceived by the girls.
   This bias is more apparent in year 8.
2. French
   23% of the year 8 students believe this subject is more suitable for boys to study. But the year 9 students have a different view - 91% believe that French is a subject suitable for all.
3. Geography
   The year 8 students believe this is a girl's subject. This attitude persists in year 9 although not as strongly. There is no gender difference in this attitude.
4. Physical Education
   Girls see this subject as suitable for all students (89%), whilst the boys (33%) see it as suitable for them only.

Employments suitability

The overall impression is that for the 19 occupations listed the students perceive them in the traditional way. For instance, a beautician is seen as a female occupation by both sexes; a computer technician is for all or the the boys and a dentist is a male occupation according to 40% of the students.

A number of other comments should be made;

1. Air traffic controller
   There was no support at all for this as an occupation for girls.
2. Doctor
   Was seen by both sexes to be suitable for both sexes but with a slight edge for the boys.
3. Geologist
   It is interesting to note that 77% of the girls saw this as relevant to both sexes. The remainder said it was a male occupation.
4. Nurse
   The results are not surprising but should be noted. 2/3 of the boys see this as a female occupation, but the girls were evenly divided as to suitability for all and a female only role. This view was shared by both year levels.

PARENTS

Experience with science

Very few parents in the sample interviewed had tertiary training of any kind. Several "dads" were Engineers, and a couple of "mums" had been school teachers. Almost an equally small number of parents were involved in scientific or technological fields of employment, (electrician, laboratory technician). Most parents had completed their formal science education at year 10., and they did not see science as relevant for their daily lives.

Support or encouragement

In general study

Most parents perceived their daughters as wanting to do well at school and they were encouraging this. However, science was not seen as being any more important than other subjects. Many parents were unaware of how their daughters were performing in science. some parents reported that their daughter was doing poorly in mathematics and so could not succeed at science.

Towards a career

Science was only considered to be an important subject if required for a particular career. Conversely English and Mathematics were considered to be the most important school subjects, both as essentials for a career and for general living.

In general, most parents would like to see their daughters get a 'good job', but have limited aspirations for them, even though in half of the families interviewed the daughters were achieving high marks in science.

Several parents stated that science was an important subject for their son's career and most said they would want their son (if they had one), to continue science to year 12.

One mother wanted her son to continue to study science to year 12 even though his ambition was to be an accountant. At the same time she felt that her daughter would not need science although the daughter had expressed an interest in joining the Army.

CONCLUSIONS

As the pilot project has only been in operation for one semester there are no profound statements that can be made. What we have at present is the base information for comparison of all data over the duration of the project. Cross tabulation of the data to date has begun. However it should be re-iterated here that there appears to be a lack of understanding by the parents' as to the reason for the all-girls classes at the school and that this situation may be due to the fact that in this school community we have the typical sex-stereotyping roles and attitudes existing. The big question is, Will this intervention strategy of single-sex science classes be effective in altering the girls views about what is appropriate for them to study or follow as a career?

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APPENDIX

EVALUATION SCHEDULE

TIME	TEACHERS	STUDENTS	PARENTS
Nov/Dec. 1986	Survey of attitutes.	Achievement levels in science. Attitudes to science. Employment future for self & others Ranking of students.	No contact except for daughter's choice of group for science.
April/June 1987 ditto 88	Some classroom observations.	Collection of semester results.	Interviews of a random sample parents with daughters in year 9 or 10 either all girls or mixed science classes.
July/ Aug 1987 ditto 88	Interviews.	Interviews with sample from both all girls & mixed classes.	Interview with random sample with sons in year 9 & 10.
July - Nov. 1987	Video of lessons. (ditto 88)		
Nov/ Dec. 1987 ditto 88	Interviews.	Achievement levels. Attitudes survey. Interviews.	Interviews.

Research In Science Education, 1987, 17, 113-116.

EXPLORING IDEAS ABOUT MAGNETS

John Bailey, Rod Francis and Doug Hill

In recent years there has been a great deal of interest in contrasting students' ideas about events or instances with those of scientists. While earlier research focused on specific explanations of particular phenomena, more recently attempts have been made to find features which are common to ideas spanning several areas of science (Driver, et al, 1985).

It appears that students may have both general constructs which they attempt to apply universally in understanding events as well as specific constructs which they apply only to events of which they have concrete experience. Glaser (1984) has argued that both domain-specific knowledge and general schema are used to interpret events, with the latter being more important in unfamiliar circumstances. Information which has been obtained in specific situations may eventually give rise to generalised schema, however, the experiences which give rise to the schema cannot be recalled.

Andersson (1986) has claimed that general schema arise as a consequence of the way in which children construct their ideas about cause and effect in everyday situations. Because these ideas have worked in a wide variety of situations, they use them in science if they have no firm specialised knowledge of the particular event or instance. Two of the general constructs which Andersson suggests are held by many children are: (i) that in any interaction, the newer the agent, the greater its effect, and (ii) the larger the agent the greater its effect.

It was decided to investigate whether or not children used their general constructs in predicting the behaviour of interactions involving magnets. The authors had already started to examine children's ideas about magnetism as this is a common topic in school science curricula which has not been extensively studied. Selman (1982) and Andersson (1986) have carried-out and reviewed some preliminary investigations with electromagnetism but magnetism more generally, and plastic strip magnets specifically, do not appear to have been studied in connection with children's naive science concepts.

The use of Andersson's general constructs (or Gestalts of causation, as he refers to them) were investigated in regard to primary school children's ideas about plastic strip magnets of the type commonly used in the sealing slip of refrigerator doors.

PROCEDURES

It was decided to use individual interviews as the method of eliciting students ideas. 119 primary school students, from two schools, with approximately equal numbers of girls and boys in year 2, 4 and 6 were the subjects.

Each student was shown the strip of plastic magnet and their ability to pick up metal paper clips was demonstrated. They were then asked to complete two tasks.

> Task A - the student was shown equal sized strips of plastic magnet (7cm long) and told that one strip was new while the other had been taken from the door of an old refrigerator. The student was then asked to predict which magnet would pick up the greater number of paper clips.

The predictions was recorded together with the student's explanation of his/her prediction. The student was then asked to test the prediction.

Finally, the student was asked what previous experience he/she had had of magnets and this was recorded by the interviewer.

> Task B - this task was given in two, parallel forms. The first form was given to 62 students and the other to 57 students.

In the first form of task B, the student was given a 7cm strip of plastic magnetic strip, and pair of scissors and a ruler. The student was asked to cut the strip exactly into halves (each student chose to cut it across the short axis).

The student was then asked to predict how many paper clips would be picked up by one of the half strips. The prediction and students' explanations were recorded.

The student then tested the prediction.

In the second form of task B (task B^1), the student was shown 3 magnetic strips and it was demonstrated that two of the strips were each half the length of the third.

The two shorter magnets were then held separately some distance apart, and the student was asked to predict the total number of paper clips which would be picked up by the strip held in this manner. The prediction and student's explanation were recorded before the student tested the prediction.

RESULTS

Task A

53% of the students predicted that the newer magnet would pick up more paper clips than the older magnet, while 38% predicted that both magnets would pick up the same number. 9% predicted that the older magnet would pick up more paper clips than the new magnet.

Students who predicted that the newer magnet would pick up more, typically gave reasons such as:

> "Old magnets have less energy."
> "[A magnet] loses its power as it gets older."
> "[A magnet will] hardly even work if old."

Students who predicted that the newer and older magnets would both pick up the same number of paperclips, gave reasons such as:

> "Still looks like the same material."
> "[In my experience] some magnets don't lose their power."

Student who predicted that the older magnetic strip would pick up more paper clips than the newer strip, gave reason such as:

> "Gets stronger as it get used - get used to being stuck to things."

Test B

60% of the students predicted that the shorter magnetic strip would pick up fewer paper clips than the longer strip, while 31% predicted that the longer and the shorter strip would pick up the same number. 9% predicted that the shorter strip would pick up more paper clips than the longer strip.

Students who predicted that the shorter strip would pick up fewer paper clips, gave reasons such as:

> "Less magnetic energy left because it is cut in half."
> "A bit gone so it will hold a bit less".
> "Less of it to pull."

Students who predicted that the longer and shorter strips would pick up the same amount, gave reasons such as:

> "Each end can hold six."
> "Same width - that is where they are held".

There was no significant difference between the predictions or explanation given by girls and boys or by students in different years. Neither did previous experience of magnets correlate with the type of prediction or explanation.

DISCUSSION

The results of this small investigation lend support to Andersson's suggested general contructs. For, although the old magnets were unaffected by age and held exactly the same number of paper clips as the new magnets, 53% of the students appeared to think age would reduce the magnet's strength. This is consistent with our everday experience in many fields from motor cars to batteries where use/age results in deterioration.

Similarly, a large percentage (60%) of students seemed to use the general construct, "the larger the agent, the greater its effect", in predicting that a large strip magnet would hold more paper clips than one half its length. (The magnets used held the same number of clips irrespective of length).

It is of importance, that the previous experience of students with magnets which ranged from formal teaching, considerable home experience to very little experience, did not appear to affect their predictions. This suggests that the students were using general schema to address the problem rather than domain-specific schema derived from previous experience with magnets.

We would suggest that this is a useful field for further investigation. This initial study lends weight to the idea that children develop general schema or constructs from everyday experience of a wide range of phenomena and that these general schema are unlikely to be revised through a small number of domain-specific exceptions. Perhaps a wider range of experiences and a greater period of time than has previously been employed is required to help children develop schema appropriate to scientific explanation.

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ENERGY IN THREE NEW ZEALAND SECONDARY SCHOOL JUNIOR SCIENCE CLASSROOMS

Malcom Carr, Valda Kirkwood, Barry Newman
and Ralph Birdwhistell

INTRODUCTION

The learning in Science Project (Energy), abbreviated to LISP (Energy) is a 3 year project funded by the New Zealand Department of Education to investigate teaching and learning about the energy concept in New Zealand primary and secondary schools. The work is carried out in the Science Education Research Unit (S.E.R.U.) at the University of Waikato, Hamilton, New Zealand.

Early in the project science educators (primary teachers, secondary teachers, primary science advisors, science inspectors, Teachers' College lecturers, Education Officers), indicated that the energy concept held by teachers of science was often influenced by their subject, chemistry, physics and biology. (Kirkwood et al. 1986).

The second phase was classroom observations of teaching and learning about energy in three secondary schools. The junior secondary school (Form 3 and 4, 13-15 year olds) was chosen since there is a specific topic Energy (Level 5, Section 3, Form 1-4 Draft Science Syllabus, N.Z. Department of Education, 1978). Teacher support material in the form of Trial Guidelines is available and extensively used by teachers. The concept energy is also integrated throughout the rest of the syllabus.

Three Working Papers (304, 305 and 306) have documented teaching and learning about the topic Energy in three separate classrooms at the three different schools. The Working Papers describe the lessons in detail but make few comments on events in the classroom. Readers are left to form their own impressions. This overview paper describes the researchers' perspective of the three classroom case studies, particularly reflecting on aspects of the Guiding Principles which are outlined in Working Paper 302 (Carr et al 1986).

ANALYSIS OF THE CLASSROOM OBSERVATIONS

This overview paper now discusses the three case studies using themes from the Guiding Principles. A number of other aspects of teaching and learning about energy will also be considered.

SYSTEMS UNDERGOING CHANGE

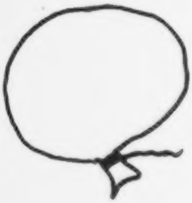
Guiding Principle 1 suggests that "it is necessary to analyse systems undergoing change to clarify the concept of energy".

LISP (Energy) researchers considered that Energy as a concept is more sharply-focused when a defined system undergoing a defined change is considered. A number of features of the case studies illustrate this suggestion.

1. Static Systems

Discussion of energy associated with static systems causes many conceptual problems. We have found that consideration of a number of static objects (of equal mass) on a shelf has often helped to clarify the difficulty that current teaching practices might cause for students: Which of a 1kg battery, 1kg of dynamite, a 1kg magnet, a 1 kg compressed spring, a 1kg rabbit, 1kg of hot water etc. contains the greater amount of energy? The question is unanswerable until what happens next is defined. If the objects all fall to a shelf one metre below then the amount of energy available is the same. Other changes to the objects (burning them, connecting them to a bulb ...) provide different amounts of energy.

This way of looking at energy was not explored at all directly in the case studies, rather the teachers followed current practice in texts and other curriculum materials where assumptions of what happens next are implicit. Students do not always make the same assumption.



Student Answers

kinetic	1
*gravitational	5
potential	3
strain	3
kinetic → gravitational	1
chemical	1
no answer	2

[Case Study A,24]

2. What Change?

A full spectrum from clearly described, through strongly implied, to ambiguous changes can be seen in the energy lessons described. Students mostly considered a change similar to that of the teacher but understandable confusions can occur when the change is not stated, and several plausible possiblities exist. Students apparently consider changes different from those focussed on by the teacher. Thus part of one question in School A's End of Topic Test was: Identify the main form of energy show in the diagrams.

The teacher's change from this static situation involved a change in height and therefore gravitation energy. Students implied other changes e.g. that the balloon was stretched, therefore strain, that the balloon was moving, therefore kinetic.

Clear statements of any change being discussed, so that initial and final states of a system are agreed by teachers and students could be a powerful contribution to clarification of the energy concept.

Even when defined changes were explored the situation can be very much more complicated for the students than for the teacher.

3. Potential energy (stored energy)

The above discussion of the amount of energy in static systems points to difficult problems when the concept of potential energy is introduced. To ascribe a particular kind of potential energy to a static object is really to imply a clearly defined change. Thus a raised object can be said to have "gravitational potential energy" if the focus is on its mass and distance from a centre of mass. If the object is a stick of dynamite it also has "chemical potential energy". Should it be detonated rather than, say, dropped. If it is also charged with static electricity, it has "electrical potential energy". In the case studies there are clear and understandable signs of bewilderment about potential energy as the End of Topic Test question in Case Study B indicates.

Question 5 (Teacher's answer*)

5. Some energy forms are said to be stored for later use. This is called energy.

Give 3 types of this energy.

a ____________ b ____________ c ____________

*Potential	26
Stored	2
Kinetic	2

Types of potential energy (Teacher's answer: chemical, elastic gravitation was not given by any student)

Electric, gravitational, chemical	7
Rubberbands, woundup springs	3
Sound, heat, electricity	1
Battery, torch, rubberbands	1
Battery, rubberband, woundup spring	1
Light, sound	1
Heat, light, sound	1
Battery, rubberband, dynamite	1
Gravitational, battery	1
Gravitational, elastic potential, kinetic potential	1
Gravitational, chemical	1
Chemical potential, gravitational potential, sound potential	1
Battery, light	1
Battery	1
Battery, bomb, lifted object	1
Potential, GPE, electricity	1
Battery, light bulb, people	1
Battery, electric, sound	1

[Case Study B. 55-56]

4. "Simple" energy changes

The case studies describe resourceful teachers and students confronting energy changes in the "Energy Circus". The transformations explored invoked many more energy changes than may have been expected when the experiments were selected for study. Any carefully specified change to a system involving energy transformation must involve at least two energy forms. Real systems escape the scientist's reductionist view, and freqently involve many more than two forms. Even when the boundary to the system is clearly understood many "simple" systems (e.g. heating a thermocouple connected to a galvanometer) invoke alternative ways of looking at the system than the expected heat - electrical.)

DEFINING THE SYSTEM

Guiding Principle 2 suggest that for analysis of "a system undergoing change, it is necessary to describe the initial and final conditions." The case studies reveal many confusions which warrant careful consideration of this principle.

1. Is the system defined?

It is frequently possible for teacher and student to have different views of what the limit of consideration (i.e. the system under study) is. This takes several forms.

Does the system start from the sun? The concept of tracing energy back to the sun is often introduced by teachers and text books. Two of the teachers introduced this idea early and it was an important feature in their discussions. (These teachers had a significant amount of biology in their degrees.) The third teacher, whose background was physics, made use of the idea only in a restricted part of a lesson (and a question in the End of Topic Test requiring an energy chain starting from the sun confused his class). Two points can be made about energy chains tracing back to the sun:

(i) Many such chains are neither simple nor sensible. Beginning from a wall socket providing electrical energy there are many possible chains to the sun (e.g. via hydroelectric, coal-fired or gas-fired power stations), and no good reason for choosing the test book variety rather than a host of alternatives. The procedure introduces unnecessary confusion and may be better restricted to specific comments about the sun and biological systems, and a general discussion about the sun as the major energy source.

(ii) Some questions become highly ambiguous as to whether the sun was involved. Consider the following two questions:

A. What is the original source of energy a man uses to do his work?
a the Earth b the food he eats c the sun d his muscles

Is the trick to answer the sun to any question such as A? If so, this is a trivial analysis. What about question B?

B. The chemical energy in our bodies comes from:
a sleeping b eating food c drinking water d sitting in front of the fire

Why is the sun not an alternative here? The problem is one of consistency. Students could well be confused by their interactions with a teacher who shifts from system including the sun to more limited systems. Confusion is even more likely for student taught by several teachers who discuss energy from different, and undeclared, frameworks some of which include the sun, others being more limited.

2. Is a person included in the system?

Beginning, as many students do, with a person-centred view of energy - "I need energy to get things done" - there is often a reluctance to exclude a human operator from a system undergoing change. "Simple" systems such as an object being dropped trigger comments about the person dropping the object, their muscles operating, movement fingers etc. Operating switches in electrical circuits is often, and understandably, seen as part of a system to be analysed. The scientist's reductionist view of the world which excludes an, (often necessary) operator from a system - the battery is connected, the light is switched on, the match is lit etc. by some invisible, insubstantial agency - needs to be openly acknowledged and agreed to as an unreal but necessary simplification of the complex system being studied. Simply removing the mover with discussion can reinforce the view that school science is an unreal game with no relevance to the real world.

John, in School B, addressed this problem by clearly excluding the person involved in lighting a match.

> J We'll start with the idea that the match is already lit because that's strictly right. So where would it be after you've lit the match? From a lit match point where do you go? [Case Study B, 60]

ENERGY AS THE NON-MATERIAL FACTOR OF CHANGE

Guiding principle 3 addresses the concept of "energy as a non-material factor in the change."

1. Energy resources

The case studies revealed (as have many previous studies) considerable confusion of energy resources with energy. Discussions about conservation of energy frequently become entangled with energy. Discussions about conservation of energy frequently become entangled with conservation of fuels. The confusion can be seen in the lessons described e.g. when energy chains feature energy resources and when energy chains such as the following are written:

sun → coal → steam → steam energy
coal → heat → steam → electricity

As Sue in School A comments:

> Looking at the way the students have tried to do energy chains, dealing with New Zealand, I think, hydroelectricity, coal and natural gas and sometimes they weren't sure what energy and what wasn't energy. They could get a chain to follow a process. They weren't always following it as being energy because they weren't quite sure what was energy and what wasn't energy.

When students are confused between fuel and energy, and when current media attention focusses strongly on the need to conserve fuels (or often energy) it is not surprising that conservation of energy present conceptual difficulties.

2. Energy flow from the sun

There is a subtle problem with the concept of energy flow. It is understandable that students may link the idea of flow with a material substance (however attenuated).

FORMS OF ENERGY

Guiding Principle 4 states that "Energy exists in a variety of forms, e.g. light, sound."

Early in each case study the possibility of different forms of energy was introduced, and this aroused considerable interest in students. Comments such as "I didn't realise there were so many forms" were frequent. As more forms were uncovered some understandable confusions also surface.

1. How many forms are there?

In the excitement of evoking new forms students face the problem of when to stop. Many instances such as muscle energy, swallow energy, smell energy are understandable extensions to the category energy. Eventually a number of the forms will be collapsed into kinetic energy, but too early reduction from the exciting variety may not be helpful. It would be more valuable to link the forms to the concept of involvement in getting things done, where this is possible. In the case studies the new forms of energy accepted were not always discussed as being involved in getting things done. One unexpected problem exposed by analysis of the lessons was, however, an incorrect link between energy and getting things done.

2. Signal vs energy transformation

If energy is linked to getting things done then discussion needs to clearly distinguish energy transformations and signals which can cause a system change. An order (sound energy) causing an entire class to sit down, or to leave the room should be seen as very different from the energy transformations subjected to analysis in terms of energy conservation (see later). An S.O.S. (light energy) causing an ocean liner to change course; a pop concert audience dancing to the beat of music; the engineer pushing a switch (kinetic energy) which causes a large detonation - all of these changes are different from those which energy conservation applies.

3. Potential energy

Some students separate the word "potential" from any qualifying energy form, seeing potential energy as a separable energy form (and stored energy similarly). In this way a difficult concept becomes extremely ill - focussed and can verge on the meaningless. Attachment of potential to an energy form or not resulted in the considerable variety of responses to the question below, from Case Study B.

In the space provided list 5 different types of energy.

Of the responses from 25 students, 17 put potential on its own, 4 added the descriptor of gravitational to potential, 1 wrote chemical potential, 1 elastic potential and 1 electric potential [Case Study B. 34-35].

A further difficulty with the word potential is the meaning "what-is-to-come" as in: she is potentially a world-class runner, he is a potential criminal. Confusions about whether a battery can be said to have chemical potential energy or electrical potential energy (or light, heat and sound potential energy because it may light a bulb or ring a bell) are understandable for this reason. Patricia, in the following exchange from an experiment when a peanut was burnt, exemplifies the problem.

P The peanut has got a lot of heat energy
V Where do you think that heat energy came from?
P It was probably stored but it came out when it was heated.
V What sort of energy was stored do you think?
P Potential
V Any particular form of potential energy?
P Heat. [Case Study A, 72]

Linking "potential" to "stored" does not seem to resolve this difficulty, and can for some students mean yet another difficult concept to acquire.

Karen worked very hard to cope with potential and stored:
K Well I understood what potential energy was because I didn't really understand what that was before
V What do you understand by it now?
K Well, it's energy that can be stored. And actually before it happens so stored energy is sort of different. So I understand that better than I did.
V What do you think you understood it as before?
K Well I just sort of assumed that they were the same thing.
V What, how do they differ?
K Well potential energy is something that can be stored and stored energy is stored.
V Karen you were telling me that you'd got all sorted out about potential yesterday. Can you remember what you were saying to me yesterday about potential energy?
K Well it's something that has energy it can be done where stored has got to be moved.

Four days later in an investigation as to why Karen wanted to alter earlier transcripts the following emerged:

K That was when I thought potential energy and stored energy were different things ... but now? I asked Miss A. the other day and she told me that they weren't and I didn't

> see why they told us both of them ... Well when they said stored energy I thought it was different because the way they sort of worded it. Like potential energy is the scientific way of saying stored energy. So now I sort of understand that they are the same things but I was a bit confused when they just said they were two. So I understand better now. [Case Study A, 31-32]

Whether the concept of potential energy is required at this level, rather than clear statements about defined changes being the focus of discussion is a matter worthy of serious consideration.

5. Chemical energy and gravitational energy

The previous transcript, and many other case study instances, indicate students' problems with chemical and gravitational energy. As soon as chemical energy is introduced then the presence of materials (chemicals) in all systems causes confusion. Why is chemical energy not being discussed? This seems to nag at some students, and the problem may be lost in the rich interaction which discussion often provokes. Eventually a change in chemical composition needs to be seen as a significant change to the system - Guiding Principle 2(ii) - but often this clarifying point is not made. A further problem is that chemical energy is more removed from sense experience than heat, light, sound. Students may need help to see the need for chemical energy. This help could come from two sources; linkage to "getting things done", and consideration of energy conservation systems.

The latter analysis would explore the view that a change of a system involving an increase in some form of energy (heat) a decrease in other forms of energy (chemical). More adventurous teachers may even explore the view that chemical energy is an invented form of energy to save the principle of conservation of energy.

Gravitational energy causes problems for students which parallel those for chemical energy, and can be even more conceptually severe. Here the linkage to "getting things done" is very valuable, although several discussions in the case studies took a very practical view of this and left the clear impression that gravity cuts out at ground level or the floor of the classroom.

CONSERVTION OF ENERGY

Guiding Principle 5 states that "when energy changes in form, the total amount of energy remains constant."

1. Conservation of energy/resources

Other workers have described the confusion between the Principle of Conservation of Energy (energy is neither created nor destroyed) and the conflicting current consideration of conservation of energy (resources) where the world is seen as running out of energy. An intermediate, and often uncomfortable position, centres discussion on energy being lost as heat (leaving the status of heat as a form of energy somewhat cloudy). These ambiguities are clear in the case studies. Students' answers to surveys at the end of the lessons revealed the powerful influence of concerns about energy resources running out.

In the pre/post survey the students were asked the following questions. We are interested in knowing what you understand by the expression "conservation of energy".

a) Have you ever heard this expression "conservation of energy"? YES/NO

School	A		B		C	
Survey	Pre	Post	Pre	Post	Pre	Post
Yes	16	19	9	17	10	17
No	11	4	10	8	12	7
No Answer	3	9	12	3	2	0

b) If YES, please write a few sentences about what you think about when someone says "conservation of energy"?

In the pre survey the students invariably write about 'saving' or 'not wasting' energy or power or fuels e.g. Saving energy e.g. not using power needlessly; Not wasting energy on unnecessary things. Maybe using the same energy for more than one thing.

In the post survey more students said they knew about conservation of energy. Nevertheless all but three of the references were to saving/not wasting energy/power/fuel.

Three statments which refer to the Conservation of Energy Principle come form Case Study A, where the Principle was discussed and written down by students: Energy is not lost but simply changes forms; Energy is neither created or destroyed but it simply changes form; Is it changing from a one energy to another?

The physicist's concept of the conservation of energy is very difficult for students to construct for themselves, or to accept. Andrew, a very thoughtful 4th former in School A, who eventually topped the End of Topic Test commented:

> For the record I'd say that what I'd learnt at this particular stage in the year so far is that energy cannot be destroyed or created. I'm still not sure about energy can't be created. But I'll leave that for otherwise I'll get confused. I'm still thinking of how we got here in the first place. Because we've got all this energy and how was it? But anyway it can't be destroyed. (T134, 3-4)

2. Renewable and non-renewable resources

A concept which is frequently linked to fuel conservation considerations is that of renewable energy resources. This is a valuable topic for consideration in school science, but it requires careful consideration. Students were confused between fuels and energy forms (reinforced when questions like "suggest a form of renewable energy that we currently don't use in N.Z." are asked), and were uncomfortable about aspects of this new idea.

In Case Study A (p66) a question about renewable/non-renewable energies resulted in 14 out of 21 students classifying natural gas as renewable, and 16 out of 21 students classifying coal as renewable. This may have been because the fuel can manifestly be replaced from reserves (e.g. by a trip to the coal depot). In Case Study B (p80) other difficulties relating to nuclear resources, in particular, were apparent.

It may be that students use a very much more context-specific view of non-renewable. The specific meat pie that you have just eaten is non-renewable but it is replaceable!

OTHER ISSUES

Discussion of the case studies has, so far, centred on the Guiding Principles. Other important matters become apparent during the case studies. These include:

Energy as an invention

During the case studies there are times when the teacher may have welcomed some respite from the understandable desire by students to regard energy as something that in naive realistic terms "exists" "out there". Some comfort can be gained in discussion of energy as a concept invented to bring together a number of phenomena associated with change, and not existing out there waiting to be accurately described. Such a discussion fits well on the now-you-see-it-now-you-don't, chameleon character of energy, and would divert students from patient acceptance of yet another set of rules to be learnt (eventual rationalisation may or may not be provided).

Students' prior ideas

The case study teachers frequently sought students' ideas in discussion; the experimental explorations provided a rich variety in discussions. The transcripts often reveal an embarrassment of ideas trigger by what the teacher, and curriculum developer might have seen as a simple system which can be quickly explored and categorised. These students had not "learnt some rules" e.g. for reducing experience to nearly ideal, for excluding the human contribution to experiments, for deciding how to trace energy changes back to the sun. The students bring rich and sometimes challenging material to lessons (the tracing of all energy changes back to the sun had one student contemplating falling rocks in another galaxy). Frequently the impression is of lively players trying to comprehend the rules of a game, and being provided with not one code, but a number of conflicting codes.

An approach in which students' ideas are exposed and interacted with, informed by the guiding principles, is being trialled in the next phase of LISP (Energy).

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TEACHERS AS RESEARCHERS: THE RATIONALE; THE REALITY

John Baird, Ian Mitchell, and Jeff Northfield

In 1985 and 1986, the Project for Enhancing Effective Learning (PEEL) was conducted at Laverton High School, Melbourne. The project was an attempt to improve the quality of teaching and learning at the school. Its primary goal was to train students to take greater responsibility for, and informed control over, their own learning. In order that this occur, both teachers and students needed to undergo substantial personal development; they had to move to a position where both were willing and able to collaborate in promoting effective independent learning.

A fundamental feature of the project was the method by which change was fostered - a style of teacher action research. Over the period of the project, seven teachers participated for both years, and eight teachers for one year. Throughout the project, teachers collaborated continually with each other and with 'outside' consultants regarding aims, methods, organisation, and development. As will be described, the further the project progressed, the more the teachers initiated decisions made.

According to a variety of criteria, the project succeeded (Baird & I. Mitchell, 1986a). Perhaps the greatest success of the project, however, did not lie in the original goal - that of enhanced student metacognition. It was in demonstrating the extent to which, if given the opportunity and appropriate conditions, teachers can illuminate and change school practice. It highlighted the fact that research which is carried out by teachers in their classrooms can be significant and substantive. It showed that such research can help redress a current problem in much educational research - the gulf between educational theory and the practice of education. The purposes of this paper are to draw on the experience of PEEL to identify some conditions considered necessary for effective teacher action research and, particularly, to argue for a style of research which has the potential to influence and advance understanding of theory and practice together.

FINDINGS FROM PEEL

Three outcomes of PEEL are directly relevant to the thesis of this paper. Each outcome bears on the process of personal change experienced by the participants. First, all types of participant (teachers, students, consultants) showed clear evidence of significant intellectual development involving attitudes, perceptions, conceptions, and abilities. Teachers moved towards fulfilling their professional potential in various areas - learning, teaching, research, and communication. Through the project, they learned at least as much as the students about themselves and their role in the classroom. They learned about their own teaching and, indeed, taught themselves how to teach in a way which was more satisfying to them and more productive for the students. They also learned how to research their teaching and the students' learning, so that they became more able to make informed decisions, based on perceptive evaluation of their practice. Further, they learned much about effective interaction with their peers, mainly as the result of weekly project meetings, where ideas were shared and evaluated. They learned how to document and communicate their findings to others, by means of books (e.g. Baird & I. Mitchell, 1986a) research and media articles (e.g. J. Mitchell & Baird, 1986), and in-service workshops and media interviews. Two of the teachers have incoprorated the understandings gained from PEEL in the production of student texts and curriculum materials (e.g. Jones & J. Mitchell, 1987).

As a direct consequence of these gains, the second outcome relates to the commitment of the teachers to the endeavour. In order that, over a period of two years, teachers continued to subject themselves to the considerable time, emotional, and professional pressures inherent in this style of research (and which the teachers pursued without any time relief from their full workload), there must have been concomitant pay-offs for them. Almost without exception, teachers' attitudes and commitment to the project and its goals strengthened the longer they were involved. It is significant, that, even though the project was formally completed at the end of 1986, 22 teachers at Laverton have decided to continue the study in 1987. Further, one teacher who left the school at the end of 1985 has established, and is currently convening, another group of 10 teachers at her new school.

The third outcome is that the results have been obtained seem to have a relevance and validity which make them valuable to other practitioners. Already, the first book from the project (Baird & I. Mitchell, 1986a), containing 12 chapters written by the teachers and one by a student, has sold over 600 copies through private distribution. The book has been prescribed as a tertiary education text both in Australia and overseas, and single schools have purchased up to 15 copies. In the next section, these outcomes will be considered with a view to discovering why the project was so successful for these teachers. Subsequently, some implications of the findings for education theory and practice will be elaborated.

INTERPRETING THE FINDINGS

Why was PEEL so successful? Of the many possible explanations, two which relate to the substance of the project will be considered here. These explanations relate either to the focus of the project, or the methods used in it. The focus of the project was metacognitive training of the students - having the students more knowledgeable about their own learning, more aware of the nature, purpose and progress of their current learning task, and more able to make informed, purposeful decisions for its management. Teachers commenced the project very aware of, and concerned about, student deficiencies in these areas. One fundamental reason for them joining the group was a desire to help the students overcome such deficiencies. Thus, it may be that this focus provided sufficient motivation and impetus to see the project through.

Alternatively, it may have been that the methods employed to foster teachers' participation and development provided, of themselves, sufficient positive reinforcement to ensure the teachers' cooperation and commitment. There were two such methods. First, throughout the two years, the teachers worked as members of a tight-knit supportive project group. The group provided stability, recognition, and encouragement to persevere. Secondly, the mixed composition of the group meant that the teachers were not alone; they had access to ideas, theories and experience from the outside world. Could it be, therefore, that the focus of the project was relatively incidential - that simply by providing teachers with such a shared support structure will ensure effective progress towards any goal deemed worthwhile by the group?

We believe that the principal reason for success may draw on aspects of both these alternatives. The basis for this explanation may be found by emphasising the similarities between the processes leading to the positive outcomes for the students and those for their teachers. First, the student changes will be described.

In the project, the metacognitive training of students required them to practise methods for enhancing self-awareness of learning through purposeful enquiry, reflection and evaluation, and control of learning through informed decision-making. These methods were based on individual enquiry in a group (class) context, which actively encouraged and reinforced such enquiry. Through the project, many students showed evidence that they had moved to a situation where they now accepted responsibility and control for their learning. Indeed, for these students, perhaps their greatest reward came from this feeling process of personal development would not have proceeded very far if four related requirements were not met. These four requirements are an extension of Hewson's (1981) three conditions for student learning. The change should be intelligible to the student (comprehensible in terms of what is known), plausible (consistent with what is known), feasible (able to be enacted in the normal classroom context), and fruitful (bring some benefit). The challenge of the project was to facilitate the fulfillment of these conditions for the students. In summary, then, improvement in student learning outcomes was inextricably linked to various other facets of their metacognitive development, culminating in effective metacognitive control of their own learning. This control was strongly reinforcing for the students, and it was a prime motivation to persevere.

A directly analogous process of metacognitive development seems to have operated for the teachers. As with many students, the teachers started the project largely dissatisfied with their classroom performance. They felt that they lacked understanding of the *meaning* of what was happening in their classrooms, and thus they lacked the ability to control and improve the situation. The basis of the project, in general terms, was intelligible and plausible to them, and salient to their needs. Through their action research, they were to evaluate the plausibiltiy, feasibility and fruitfulness of changes to classroom behaviours and, by developing personal understanding, make the task even more intelligible. As they participated in the project, the teachers became more *aware* of what was happening in their classrooms. Learning ways of increasing the students' awareness inevitably accelerated the development of the teachers' classroom awareness. With this enhanced awareness, came the potential to *control* classroom activities in order to more effectively pursue desired learning outcomes. Enhanced metacognitive awareness and control of teaching and learning went hand-in-hand with enhanced metacognitive awareness and control of their action research. Teachers gradually assumed more and more proficient and confident control of the direction and activities of the project. However, this process of considerable metacognitive development required time and, particularly, support. The support came from the group. Through weekly meetings and continual informal contact, the teachers and consultants celebrated successes, commiserated with failure, shared insights, and gained strength to try again.

In summary, therefore, the success of PEEL for teachers may have been fostered by a fortunate blending of focus and process, whereby:

- The project's focus of student metacognitive development for enhanced learning complemented and fostered the necessary process of teacher metacognitive development for enhanced control of teaching and research;
- group interaction and support was a necessary requirement for the continued motivation and perseverence of both students and teachers;
- the teachers' access to external ideas was an important factor in promoting both the above features.

Does this mean that all of these features are necessary in order that a teacher action research project succeed? We believe not. We believe that the focus of PEEL - student metacognitive development - is not a necessary condition for success. Any focus of direct concern to the participating teachers is appropriate to the method. However, it seems that all of the process features outlined above (teacher metacognitive development leading to teacher control of the project; group collaboration and support; access to external ideas) are necessary for long-term success. Some points regarding each of these requirements will now be made.

Metacognitive development and teacher control

The recent Australia-wide emphasis on fostering school autonomy and school-based curriculum development seems to carry with it the presumption of increased direct teacher involvement in curriculum research and development and educational decision-making. 'Increased teacher control' is a phrase which is bandied around to signify some laudable but ill-defined component of a similarly ill-defined idealogy associated with improving the standard of education. The phrase is subject to serious misuse. Teacher control should not mean 'Here is a new idea (innovation/curriculum/program or policy). Give it to the teachers and back it up with appropriate guidelines and materials. Give them the responsibility for its implementation and all will be well!' The fault with this reasoning is that it confuses ownership with control. Certainly, any innovation has an enhanced chance of successful implementation if the teachers feel that they 'own' it - that is, they support it and are given the opportunity to translate it into practice. But ownership is not enough. Control must be developed over time. The process of implementation shares some features in common with action research. Implementation requires evaluation and reflection. It requires development in awareness of pitfalls, factors influencing success, constraints on use. It requires development of personal meaning, understanding, competence, metacognitive proficiency and confidence. It requires learning. With learning comes the potential for more informed, purposeful decision-making, i.e. control. Based on the findings of PEEL, two factors which should foster progression towards teacher control through effective decision-making are considered next.

Group collaboration and support

Based on the PEEL experience, it seems likely that only an exceptional teacher would persist with action research on a substantive educational issue if he or she acted alone. There seem to be too many conflicting pressures and disincentives. Further, if acting alone, it is quite possible that any influence achieved or any changes made with regard to student attributes or behaviours may soon fall victim to the inertia of the wider school context. Moreover, group collaboration promotes metacognitive awareness in its members through debate of different points of view, provision of informed feedback and evaluation, and shared reflection.

Access to external ideas

An important finding of PEEL was that on-going participation in the group by members from the tertiary sector facilitated these processes. Indeed, in its early stages, this input was a necessary condition for the project's continuance. This is not to say that these external members controlled the project. Throughout, options for action were shared and discussed fully and decisions made cooperatively. However, the tertiary members did provide for the teachers' consideration some conceptual, methodological and attitudinal perspectives which assisted their initial efforts at collaboration, reflection on practice, and action research. As the teachers developed their proficiency and confidence, the necessity for such input diminished. It should be emphasised that, through their participation in the group, the tertiary members enhanced their perception, conceptions, and attitudes regarding the nature and process of teaching, learning, and action research.

We reject the notion that the nature and quality of teacher action research is somehow diminished by an external influence on the group. Based on these findings, it seems that the potential for 'outside' members to facilitate effective group-based teacher action research may be currently inadequately appreciated.

IMPLICATIONS OF FINDINGS FOR THE THEORY AND PRACTICE OF EDUCATION AND EDUCATIONAL RESEARCH

Long-term improvement in the quality of education depends on a productive integration of theory and practice. However, we still fall far short of this goal - only recently have concerted attempts been made to search for meaning in observed practice. In Fullan's (1985) words:

> 'We have learned virtually nothing about how to integrate theory and practice in teacher education in the 80 years since Dewey's (1904) article on the relation of theory to practice was published.'
> (p.195)

Meaning, especially for teachers, has not been effectively derived from the majority of previous educational research. Research findings have been criticised by teachers as 'trivial ... irrelevant ... [and] of no practical use to any classroom teacher' (Osborne, 1985, p.14). Two reasons for these inadequacies are that much research has ignored the complexities of classroom context, and has not utilised the considerable potential for productive teacher involvement in choice of questions to be explored, methods to be used for gathering, analysis, and interpretation of data, and in presentation of findings. The potential of teacher reflection on practice for generating meaning for this practice is recently being acknowledged (e.g. Schon, 1983). Also due recognition is now being given to the perspective that educational change is a process which required individual change (e.g.

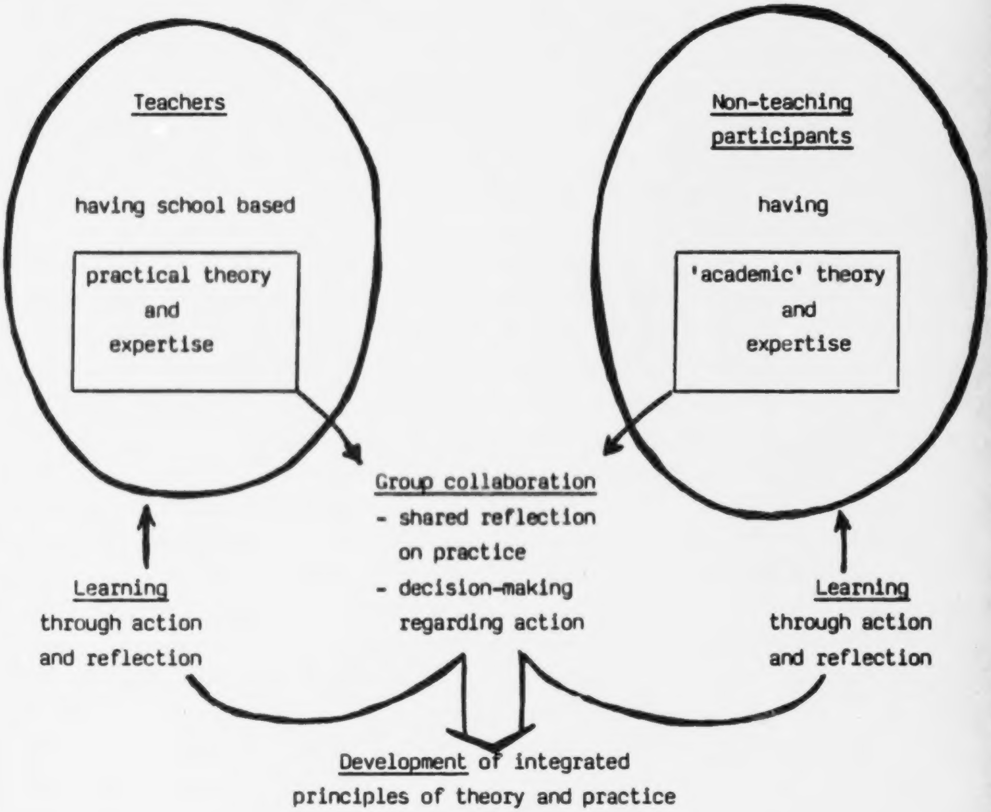
Teachers
having school based
practical theory and expertise
Non-teaching participants
having
'academic' theory and expertise
Group collaboration
- shared reflection on practice
- decision-making regarding action
Learning through action and reflection
Learning through action and reflection
Development of integrated principles of theory and practice

Figure 1: Proposed style of Collaborative Action Research

Hall & Hord, 1987). The four requirements intelligible, plausible, feasible, and fruitful were mentioned earlier to emphasise that change in practice will not occur if certain personal conditions for the participants of change are not met. The concerns-based adoption model (Hall & Hord, 1987) focuses on the different concerns that participants have as they undergo personal change. The initial concerns (related to personal reservations, and informational and organisational needs) require a different type of assistance than that which might be provided for teachers at a later stage of development (related more to adaptation, initiation, and control of procedures).

Consistent with the above perspectives, there is growing evidence for the need for two general conditions for change, both of which were observed in PEEL, and which have been mentioned above. The first is the need for time, to allow for the personal development involved. The second is the need for group cohesiveness and support.

While these two conditions for change are becoming more recognised, further understandings are limited by lack of knowledge of the mechanisms of change. The style of educational research advocated below has the potential to illuminate aspects of these mechanisms. One central feature of the style, the emphasis on informed teacher involvement, protects ecological validity and fosters the relevance of findings for other practitioners. Another feature, the continual reflexive interaction between the findings of these teachers and current 'academic' theory, should foster integrated development of theory and practice. The basis of this style is shown in figure 1.

The style is entitled Collaborative Action Research. According to this style, an action research group is established comprising practising teachers and non-teaching participants, for example educational researchers, teacher consultants or professional officers. The two types of participant bring to the group different insights, perspectives, and expertise. The teachers contribute findings regarding when, where and how ideas can be implemented, likely difficulties, typical outcomes, and modifications to suit different contexts. The non-teaching participants contribute more 'academic', perhaps more broadly-based educational theory. Through regular meetings and informal discussion, group members enter into a process of shared reflection on theory and practice. From such a process should arise tentative principles of theory and practice which possess apparent face validity from both perspectives. Decisions are made regarding appropriate actions to be taken, and participants then act to translate principles into practice, and to document and reflect on outcomes. Findings are then brought back to the group for consideration, and the cycle begins again. This style of collaborative action research sets practice beside theory in order to foster the coordinated development of both. In one sense, the derivation of this style represents the result of such a process.

The results of PEEL suggest that group-based collaborative action research can work to produce significant change. Among other findings, PEEL has led to elaboration and modification of theory and practice regarding some factors which influence teaching and learning. The style has highlighted some of the complexities in the mechanisms of classroom teaching and learning, expecially the subtlety of influences which give rise to differential effects with changes in content, context, personality attributes, and levels of effect (e.g. Baird & I. Mitchell, 1986a, 1986b; I. Mitchell & Baird, 1986; J. Mitchell & Baird, 1986).

CONCLUSION

Collaborative action research, a style of research which connotes involvement, commitment, and growth, has the potential to bring together process and outcome, teaching and research, reflection and action, theory and practice. It is an organising frame to foster productive blending of school knowledge and academic knowledge, through the participation of members of the secondary and tertiary sectors. It has the potential to enhance the professionalism and expertise of members of both sectors, in circumstances which facilitate personal development. It has the potential to enhance the relevance and applicability of educational research to the educational context and hence to generate real and permanent change in schools. We believe that this form of research has potential to be of value that extends beyond the direct participants and school settings in which it occurs.

The problem is of translating this potential into practice. Neither the school nor the educational research sectors are geared for such long-term collaborative research. However, PEEL demonstrates that it can be done. Educational research can be made relevant and important to teachers. Through collaborative action research, teachers can participate in improving the quality of education in our schools.

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DESCRIPTIONS AND FRAMEWORKS OF SOLUTIONS AND REACTIONS IN SOLUTIONS

Nusirjan and Peter Fensham

Although chemical phenomena were less studied than those in physics and biology by the early researchers interested in misconceptions, alternative frameworks, and children's science, there have now been a number of such studies. In Sweden, Anderson and Rengstrom (1982), New Zealand, Cosgrove and Osborne (1981) and Schollum (1981, 1982), Australia, Friedman 91982), Fensham, West and Garrard (1981), Fensham (1984), and Mitchell and Gunstone (1984) have all reported on the way students perceive and describe chemical phenomena.

No chemical studies seem, however, to have been undertaken in developing countries. The conditions under which teaching and learning occurs in many schools in these countries often differ in many respects from those in the above mentioned countries, as do the social contexts for learning that students will experience outside of school.

This study replicates, with Indonesian secondary students in an analytical chemistry course, some of the chemical studies that have been reported for students in more developed countries, but then explores students' views of related chemical phenomena that have not been reported before.

The chemical phenomena

The three phenomena chosen for the study were I. Solids dissolving in water, II. Reaction between chemicals in solution, and III. Influence of various factors on the rate of such reactions.

Several reasons determined these choices. Firstly, solution phenomena are central and recurring topics in the chemistry studies of these students because of their very great significance in analytical procedures. Accordingly, the students meet and are taught about solutions and reactions in solution in each of the years of their course. There is, thus, a reasonable expectation that the ideas they hold about the phenomena, as well as the information they know about them, would develop from the first year of the course to the third year. Secondly, the first phenomenon has been studied by Freidman (1982) and by

Cosgrove and Osborne (1981). A replication of studies with students in more industrialised countries was a primary interest as its findings would then be useful base for interpreting the data from the investigations of the second and third phenomena which which have not been studied before from a contructivist perspective.

The choice of the reacting systems was made on the criteria that the occurrence of reaction should be directly observable by the student, and that they should be of a reaction type, that the students would learn about in greater detail as they progressed through the years of the chemistry course and that had relatively simple examples with obviously variable rates. Precipitation reactions met these criteria, but so also could have reactions involving a colour change or the formation of a gaseous product.

The chemical systems used to provide the observed events for the three phenomena are listed in Table 1. The glass equipment and other apparatus were available in the school and the chemicals were purchased specially for the study.

TABLE 1
The chemical systems used as events for the interview about three chemical phenomena.

Phenomenon		Chemical Systems
I.	Solids dissolving in water	Sugar/Water; Salt/Water; $KMnO_4$/Water; Sand/Water.
II.	Reactions between chemicals in solution	Barium Nitrate and Sodium Sulfate solutions; Barium Nitrate and Sodium Nitrate solutions.
III.	Factors that influence reaction rates in solution	Sodium Thiosulfate and Hydrochloric Acid solutions (i) different concentrations (ii) two temperatures

The student respondents and their teaching/learning context

The school that was chosen for this study is situated in Padang in Sumatra. It is one of several in Indonesia that are under the control of the Indonesian Industrial Department. They have a special programme in chemistry for the senior secondary years of their students' schooling for the purpose of training them to work in factories or scientific instituations that require analytical chemistry. There is an intake of about 150 students per year and there are four years of study, each one of which is divided into two semesters. There are internal tests each semester but the important external examinations at the end of each year determine the progress of the students. In their fourth year students do intensified practical work as a project.

Although this school has some special features and would have better resources for chemical education than usual in Indonesia, its students are in a teaching/learning context more like others in Indonesia than in many schools in industrialised countries. Students primarily learn from their teachers' words and explanations because many of them do not have textbooks, which are expensive and hence scarce throughout Indonesia. The importance of being present in class to hear the teachers' words raised logistic problems for gathering the data of this study (see below).

Ten students from one class in each of the 1st, 2nd and 3rd years of the school were interviewed during the early weeks of the second semester. The students were chosen randomly, five from the upper half achievers (on the previous chemistry test) and five from the lower half achievers. In this way the study has the design features of a simulated longitudinal study. Of course it also has the limitations that such designs inevitably carry for confident association of years of study with development of ideas and knowledge.

METHODOLOGY

Because the study is concerned with students' understandings of phenomena as well as of the concepts used to describe them in chemistry, the method of Interview about Events (Osborne, 1980) was used for the investigation.

Each student was interviewed for between 15 and 30 minutes during which time a number of chemical experiments making up events that involve the three phenomena were carried out either by him or by N., the interviewer. For the first two phenomena chemical systems which were "not examples" were also demonstrated to the students. A series of main questions (with suitable additional probes) were planned to precede and follow each event. These were tried and refined in practice interviews in Australia and Indonesia before the main field work. The whole of each interview was recorded.

An example of the series of main questions for the experiments are given in the Appendix where Table A1 lists the questions for the second phenomenon, II. Reaction between chemicals in solution.

Several problems were experienced in using this method of data collection in an Indonesian school. They may also occur in other developing countries, whereas they have not been reported when the method has been used in the school cultures of more industrialised countries.

Although permission from the school principal was obtained for the study, a number of teachers were reluctant to release students from their classes for interviews. They feel under great pressure to complete the topics that are laid down as compulsory in the external curriculum statement. They are also very conscious of the fact that their words are the only primary source of learning for many students. With large classes and heaving teaching loads they cannot repeat a lesson for individual students.

As the study had the approval of the school principal the students did not question their participation in it. This cultural deference to adult authority by the students, however, made clinical interviews in the Indonesian context rather different to the trials in Australia. To be polite and to defer by agreement with an adult are common cultural norms for young people. Accordingly, youth sometimes say "yes" when they mean "no", and often play safe by remaining silent. In the school situation, students thus often find it difficult to express their opinion. They may know something but are reluctant to say it or simply cannot put it into words or sentences.

The interviewer (N.) was a senior adult figure, a previous teacher with high standing in this school. Often, in response to the main questions in the L.A.E. schedules, the students did not answer or would only answer with a single word. The use of an open-ended prompt like "Say some more" or "Can you tell me what you mean by _____?" did not help. The interviewer found himself having to offer what were multiple choice alternatives to which the student could agree or disagree with single word or short sentence answers.

ANALYSIS OF DATA

The procedures for the initial handling of the data from the 30 interviews and for analysing them are similar to those used by other researchers in this field. Transcripts were made of each student's interview and identified by A1, A2, ... B1, B2 ... C1, C2 where A, B, C refer to 1st, 2nd and 3rd year respectively and 1-5 are upper achieving students and 6-10 are lower. All the answers for each main question were then listed and grouped into categories based on their similarity of wording and their use of distinctive words or concepts. For example the categories that emerged from the Main Question 1.3 What does dissolve mean? are given in Table 2.

TABLE 2
Categories derived from students' answers to, What does dissolve mean?

1.3	(a)	Substance is broken into small particle and mixed with water.
1.3	(b)	Homogenous mixture.
1.3	(c)	Substance mixed with water.
1.3	(d)	Solid disappears in the water.
1.3	(e)	Substance is combined with water.
1.3	(f)	No answer.

The categorisation of the students' answers to each of the Main Questions enabled the occurrence of these categories among the different sorts of students (Year level and level of achievement) to be compared. An example of these comparisons is give in Table 3, in which the categories of response (Table 2) to the main question 1.3 are shown. These sorts of treatment of the interview data can be regarded as a first order analysis of them.

TABLE 3
The distribution of students' responses into the categories in Table 2 for "What does dissolve mean?"

Category of Answer	Grade A		Grade B		Grade C		Total
	High	Low	High	Low	High	Low	
1.3 (a)	1	-	1	-	1	-	3
1.3 (b)	3	1	2	2	1	1	10
1.3 (c)	-	1	1	2	2	1	1
1.3 (d)	-	-	1	-	1	1	2
1.3 (e)	-	-	-	1	-	1	1
1.3 (f)	1	3	-	-	-	1	5
TOTAL	5	5	5	5	5	5	30

When the first order analyses of the questions and answers associated with the events that exemplify the three phenomena had been completed, attention was turned to each student's complete interview. The interview recording was listened to several times in conjunction with readings of the transcript. The purpose of this repeated immersion in the responses of a student was similar to that of Marton (1981) and his colleagues, Lybeck et al., (1986) at the University of Gothenburg. It is to find the underlying framework of ideas about solutions that leads the student to give his/her set of answers. It is to answer the question, how does the student perceive chemicals in solution so that his/her descriptions of these three phenomena are what they are?

This second order analysis is concerned with findings underlying consistencies (if any) in the series of responses of a given student to the main questions. The first order analysis, on the other hand, sought consistencies (if any) of response across the answers the group of 30 students (or the sub-group of 10 or 5 or 15) gave to the same main question about one of the phenomena.

The second order analysis was carried out in a stepwise fashion from a student's answers to say a pair of Main Questions, and then linking those responses to his/her responses to other Main Questions about the same phenomena.

An example of the outcome of these second order analyses is shown in Table 4 where the students' responses about the solution events were used to identify four sorts of ideas about the dissolving process. In this case it was possible to discern one of these underlying ideas for each of the 30 students, but this was not always possible from the data available.

TABLE 4
Students' views about the dissolving process

Student's View		Grade Level	
	A	B	C
Solute becomes molecule or atom or ion and mixes homogenously	A1, A2, A5, A9	B1, B2, B3, B5, B9	C1, C2, C5, C6, C9, C10
Solute becomes small particles and mixes homogenously		B10	C3, C8
Solute becomes small crystals and mixes homogenously		B7	
Solute becomes liquid and mixes homogenously	A3, A6, A7 A8	B4, B6, B8	C4, C7

DISCUSSION

A. Solids dissolving in water

In comparing results with those by other researchers who have studied this first phenomenon, it is relevant to note that these Indonesian students would correspond in age to the oldest third of the Cosgrove and Osborne (1981) set of respondents and the older half of those of Schollum (1981) and Friedman (1982). The less verbally fluent responses of the students in the present study is also notable and makes their understandings often difficult to interpret with confidence.

As had been reported in the other studies, these students were all comfortable with the phenomenon of dissolving and used this word freely to describe the expected and actual phenomena for the events when solution occured. Perhaps because cold water was used in the events for the first phenomenon (cf. Cosgrove and Osborne, and Friedman used hot water) there were very few descriptions that used the word "melting", commonly found in other studies.

There were few obvious correlations between grade level of achievement level and type of answer. This applied to the questions Why does it dissolve", What does dissolve mean?. What form does _______ have in solution? and What happens when salt solution is evaporated?

Only in relation to the question, What happens to salt when a salt solution is filtered? did the students in the third year and with higher achievements seem likely to give answers that were more consistent with the scientists' view of this event.

The taught statement that "solutions are homogenous mixtures" came out frequently in the answers. The use of atoms, molecules or ions in describing the form of the solids in solution (16 out of 30) is more common than Friedman reports, but consistent with Cosgrove and Osborne. It no doubt reflects their teachers' use of such words and the chemical sophistication of these students. Just under half the students used the categories of "liquid", "small crystals" or "small particles" to describe the form of the solute.

The underlying meaning the students have for the words they used to describe the events becomes clearer when the second order analysis is considered. About half (and more commonly among third year students), appear to have a particle view on something like a scientists' scale. With such a view (uncoupled as it was with energy considerations) it is not surprising that they do not predict the scientists' outcome for the evaporation event.

B. Reactions between chemicals in solution

Again, there are very few findings about this phenomenon that relate to grade level and almost none that seem to relate to level of chemical achievement. Grade level is evident in the student's ability to name the product of the reaction, barium sulfate, and to use the term K_{sp}, and to refer to ions as the reacting specied.

Although most of the students expected and reported a reaction, only eight (and less than half of Grades B and C) reported the products in chemists' terms. None of the students referred to an atomic scale particle model in their answers to the questions that probed the formation of the precipitate model in their answers. We thus could not use a second order analysis to identify clearly which students had an atomic scale, particle view of the solutions and the reaction. Four students, B1, B7, C2 and C5 did speak of reacting particles and also identified correct products. Three of them displayed an atomic particle view of solutions, while B7's answers are more consistent with a small crystals view (see Table 4). The "not-example" of a mixture of non-reacting solutions did not add to our understanding of the students' views, since the questions did not evoke "explanatory" answers from most of them.

C. Factors that influence reaction rates in solution

The findings about students' views of these phenomena do reflect the teaching of this topic in the grade B year. Grade A students do not answer the factual question (IV/2) but do respond to other questions that are more speculative (IV/3 and IV/5). Only Grade B students (but less than half of them) use "particle" words in their explanations - presumably because they remembered such words from the teaching they had had earlier that year.

A sobering conclusion from the second order analyses would be that only 3 or 4 of these 30 students (i.e. about 10% or 20% if only grades B and C are considered) have acquired an atomic scale, particle view of solutes in solution and can relate it to reactions in solution and to the rate of these reactions.

However, the other studies that have been reported in relation to these sorts of phenomena also indicate that even with students at comparable grade levels, there is surprisingly little (Freidman, 1982), or no reference (Schollum, 1981 and Cosgrove and Osborne, 1981) in students' answers to a particle view of solutions. A number of chemical curricula locate solution properties of the sort studied here within a broad heading of "Particle Theory" Furthermore, most teachers could or do explain these processes in terms of words like ions or molecules that relate to atomic scale particles. Clearly this congruence of influences is no guarantee that learning about solutions and solution reactions will produce such views in students.

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APPENDIX

Table A1 The series of main questions that were asked before (X) and after (Y) the experiments associated with the second phenomenon, II. "Reactions of chemicals in solution".

II X	1.	When two solutions are mixed, what actually happens to them?
	2.	Do the barium nitrate and the sodium sulfate retain the form they had in solution separately?
	3.	Is there any change?
	4.	If so, does it mean there is a reaction on mixing?
III Y	1.	When barium nitrate solution is mixed with sodium sulfate solution what happens?
	2.	Is a precipitate produced? If so, how is the precipitate formed?
	3.	Is there any reaction?
	4.	What substance is formed?
	5.	Why does this substance not dissolve?
	6.	How do you know that two solutions will produce a precipitate?
II X	5.	When solutions of barium nitrate and sodium nitrate are mixed, what will happen?
	6.	Is there any change in the solutions?
	7.	Will the barium nitrate and the sodium nitrate retain the form they had in their separate solutions?
II Y	7.	Is there any change when the barium nitrate and sodium nitrate solutions are mixed?
	8.	What is the difference between this mixture and the mixture of the barium nitrate and sodium sulfate solutions?
	9.	Why does a precipitate not occur?
	10.	Is there any reaction?
	11.	Why do you think that?
	12.	Is it possible to make a precipitate occur in this case?

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CONCEPTUAL CHANGE: IS IT OF VALUE IF STUDENTS ARE IGNORANT OF IT?

Richard Gunstone, Robin Gray and Peter Searle

INTRODUCTION

The research reported in this paper is concerned with attempting to produce change in students' beliefs in physics, and with exploring the effects on achievement of any change. Champagne, Klopfer, and Gunstone (1982) argued a number of issues claimed to be of importance in student conceptual change. Later investigation of some of these issues (Champagne, Gunstone, & Klopfer, 1985) was in a form of laboratory context: with secondary and tertiary students not in regular physics or science courses, and with the researcher undertaking the teaching. The research reported here is in essence a further step in exploration of utility of some of the earlier ideas. Intact groups of students have been involved in their normal science courses. The teaching was undertaken not by the original researchers and not by the classroom teacher, but by a research assistant (PS) from outside the school.

Year 10 science students spent about four weeks studying some fundamental mechanics concepts via methodologies argued to be more likely to promote conceptual change. Those students who subsequently elected to study physics in year 11 were interviewed after completing the mechanics section of the year 11 course. Performance on the relevant school examination was also obtained. This paper focusses on the data obtained from the year 11 physics students.

THE CONTEXT OF THE STUDY

All data reported here are from a school situation unique in Victoria. Two year 10 science classes (a total of 46 students) in a junior (year 7-10) high school were involved in 1985. Each class was taught the funamental physics concepts alluded to above by the same person. The junior high school is referred to here as 'A' High School. A High School is one of a number of secondary schools in a Victorian provincial centre operating year

7-10. All subsequent study is undertaken by students at a separate senior high school operating only years 11 and 12. This senior school is referred to here as 'B' High School. A total number of 28 of the A High School year 10 students elected to study year 11 physics at B High School in 1986 and were involved in data collection in that year. These students were randomly distributed across five physics classes containing a total of 110 students at the time of data collection.

This location provides a form of pseudo-controlled investigation. After completing year 10, the A High School students became (in the eyes of their new school) inseparable from the other 82 year 11 physics students who had not undertaken a program with the same focus. (This statement is based on information obtained from the other year 7-10 feeder schools, not on conjecture.) The probability of uniform treatment of all students was increased by the researchers not making any contact with B High School until after students had completed the mechanics section of year 11 physics. Hence there is at least more confidence that any year 11 physics differences between A High School students and the rest might be attributable to the year 10 experience than would be the case if the year 11 teachers were aware of the year 10 experience. This made A and B High Schools an appealing location for the study.

THE NATURE OF THE YEAR 10 INSTRUCTION

A full outline of the planned instruction is available from the first author. In brief, the desired outcome was a Newtonian interpretation of the relationship between force and motion. Among the more significant of situations explored in attempting to reach this point were normal reaction (for which a modification of the approach of Minstrell, 1982, was used) and falling bodies of different mass (with both the situation of apparent equal rate of falling and the situation of obviously different rate of falling being considered). The content was generally approached in a qualitative manner.

The teaching approach was strongly discussion-based, and made substantial use of the Predict-Observe-Explain strategy (Monash Children's Science Group, 1986). In this strategy, predictions of the effect of some change on a given situation are asked for, and students' explanations of that change are sought. The change is undertaken, and student observations are obtained. Discussion is then used to try firstly to come to a common observation and secondly to reconcile differences between prediction and observation.

THE NATURE OF THE YEAR 11 INSTRUCTION

The year 11 physics course at B High School is taught in a conventional manner and involves the standard introductory mechanics concepts and problem solving skills.

Results - Year 10

A written test of understanding of concepts was given at the end of the year 10 sequence. The results are not given here, but do suggest that a considerable number of the whole 46 were able to give physicists' explanations for forces on a golf ball in flight, for normal reaction etc. A test more consistent with usual school assessment tests was also given. This second test was used to satisfy the assessment requirements of the school.

Students reactions (written) to the experience were also sought during and after the instruction. Some of these pointed to an issue addressed below in the discussion of the year 11 data. (For example, and in the extreme, a year 10 student in another school also involved in the study acieved 100 per cent on the assessment test, claimed to enjoy the approach greatly, gave a most informed statement above the relationship between the nature of the instruction and the understanding she had acquired, but also said 'we could have had more notes'.)

Results - year 11

Two forms of data from the year 11 B High School physics classes are reported here: performance on the school assessment examination in physics at the end of first semester in year 11; results of interviews conducted with the former A High School students in the year 11 physics classes after the examinations.

THE EXAMINATION RESULTS

The B High School physics examination was of a very familiar form. Questions included: given pulling force and friction force on a trolley of given mass, calculate resultant force, acceleration, velocity after given time; given a body held by a string on a smooth inclined plane, resolve the weight force and calculate the magnitude of the force supporting the weight. That is, the examination could be fairly described as typical of those commonly set in introductory physics courses. The examination also contained questions on kinematics and light. It was not possible to obtain from the school data about student performance on the subset of the examination concerned with mechanics. Thus total scores for the whole paper had to used.

The purpose of collecting students' exam scores was to determine if there was any effect on year 11 performance (as opposed to year 11 learning) after the year 10 instruction. When the rankings of former A High School students were compared with the rankings of the remainder of year 11 by the Kruskal-Wallis test, a significant difference was found ($p < .001$). This suggests that the year 10 experience was of clear cognitive advantage to the former A High School students.

THE INTERVIEW DATA

Of greater interest than this performance difference were the perceptions of the students. Interviews were conducted in August 1986. The intent was to explore:

a) students' recollections of the year 10 experience and other year 10 science classes;
b) their perceptions at the time of interview of the differences in approach between the year 10 experience and other year 10 science classes (and any preference they had for one or other of the approaches);
c) their views as to whether or not the year 10 experience had helped them in year 11 physics.

Students were interviewed in groups. The group interview, and its perceived advantages, are discussed by Van Galen, Hare and Noblit (1986), and are not elaborated here. In passing, however, we wouuld suggest that there is considerable merit in the approach when the purpose of the interview is to explore what students see as opinion (as is the case here). We would be most reluctant to use group interviews in areas where students are more likely to perceive 'right' and 'wrong' (e.g. student conceptions of scientific phenomena). Of the 28 A High School students, 26 were interviewed in six groups ranging in size from three to five. The tape recorder malfunctioned form one group of three. These groups were arranged by the school. One of the remaining two students subsequently responsed in writing to the questions on the schedule guiding the interview. Thus, interview data was recorded from 23 students and written comments from one. The three broad aspects of the interview listed above are now considered.

a) Recollections of year 10:

All but two of the 24 students recalled the name of the teacher who had taught about forces in the previous year. Where particular events from the teaching were recalled (e.g. standing on tables, dropping objects), these were recalled with quite reasonable accuracy and some sense of purpose. There is quite strong evidence that the students had reasonably accurate memories of the content of the course.

b) Perceptions of teaching approach:

Again these were quite informed, and often impressively so. The experience was commonly described as 'slow' - an accurate description in the sense that the pace of content coverage was deliberately less than typical. There was widespread recognition of the central importance to the teacher of student input and discussion, and some evidence of recognition of the purpose of this approach, e.g. 'He made sure we understood it a lot, and I suppose that's why we think it was slow'; 'We sat around and discussed the topics to see if the class could find the answer'; 'Mr S. sort of led us up to how [the theories] were formed so we could know the basis behind them'; (This was compared by this student to his perception of the usual year 10 approach - 'They taught us the theories without any background to them'.) 'We had to think for once'; 'It wasn't really teaching, it was sort of letting us teach ourselves'.

Some more general comments about Mr S's approach were also revealing: "he kind of brought everyone in ... the quiet people and the big mouth who sits there and craps on about a whole lot of rubbish'; 'He didn't have any favourites in the class, like most teachers have got a favourite boy or girl who sits there and smiles and answers all their questions'.

Of course not all comments were positive. Those who were critical almost always perceived a lack of specificity in the approach, e.g. 'We would do something and would give him answers and he would just sort of go "maybe, you could be right". He wouldn't tell us if we were on the right track'; 'He didn't really tell us any actual information - we had to figure it our for ourselves and we didn't know if we were right or wrong'; '.. and then he would ask a completely different problem and you wouldn't know from you previous experiences'; 'It takes too much time to work. We have been brought up to sort of working quite quickly and although we don't really know what we are learning we still get through all right'.

Where preference for either the usual year 10 teachers or Mr S. was expressed, it was in line with the nature of the perceptions of the approach of Mr S.

c) Did year 10 help year 11?

This was the question of greatest interest to us - could these student see the links we saw, given that they had had no prompts or assistance in the matter? Of course no student perceived the achievement advantage of the A High School group, and it would be most unrealistic to expect that they would. Exam marks then were unlikely to have been a major issue in forming answers to these questions. In fact only one student made any reference to exam performance in year 11 in their comments on whether or not year 10 helped year 11.

Of the 24 students, six essentially answered 'yes' to the question; nine said 'a bit', 'a little', 'yes and no'; three said 'probably not'; five clearly answered 'no'.

For those answering 'yes': three did so with the view that year 10 had given a basis on which year 11 built; one saw year 10 as giving a 'general understanding'; one clearly said 'yes', but was critical of 'the lack of theory' in the year 10 experience; the final student (G) said 'We understood it before we actually did it, so you had already done it before ... so you understood it without the mathematics and the definitions and you had a general idea of what was going on'. Student G had opinions nearer to ours than any other student.

Of the nine who were more ambivalent in their positiveness, one was 'surprised, it did help a bit', another felt the advantage was 'not as much as I thought it would be because I didn't do that well with forces this year' (this is the one comment interpreted as referring to exam marks), one was reserved because of the mathematical content of the year 11 course ('We had a good knowledge of what was going to happen but when it actually came down to the mathematics part of it, it was a bit difficult'.) Others referred to very specific section of content such as force diagrams, or were vague.

The five who were quite definite in the view that year 10 had been of no help expressed views which reflect the nature of their year 11 course: 'We didn't get the, like, the equations [in year 10] - how to work it out - so when we came to the actual working out it was exactly the same as [those from other schools]'; 'Ithink we would have been better off without [the year 10 experience]'; 'What we did last year was pretty limited anyway. All we did was just work out acceleration of falling objects and that sort of thing'; 'We didn't do any problems last year'; 'Physics this year consists of learning and memorizing formulae .. Many [from other schools] knew many of the formulae. I was somewhat left in the dark'.

DISCUSSION

The significant issue in these year 11 data, we would argue, is not the performance advantage of the A High School group. It is the perceptions of the students, both positive and negative, of both year 10 and year 11. The general level of insight into the nature and purpose of year 10 is impressive, especially since our agenda with year 10 deliberately did not include developing metacognitive perspectives. This metacognitive awareness is more patchy when the students consider their year 11 course. The denials of utility of year 10 are disappointing both in their own right, and in the unfortunate realism of the formal and rote problem solving emphasis so common in physics courses.

The context of the study deliberately removed almost all chance of year 11 teachers helping A High School students understand the possible value of the year 10 experience. On one hand it then can be argued that it is encouraging that some students have made these links unaided. On the other hand it seems clear to us that, for those students who are ambiavalent or negative about the year 10 experience, any performance advantage will soon decay. Without some metcognitive understanding, it is inconceivable that these students could build on any extra understanding they may have had when beginning year 11.

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STUDENT MISCONCEPTIONS ABOUT LIGHT: A COMPARATIVE STUDY OF PREVALENT VIEWS FOUND IN WESTERN AUSTRALIA, FRANCE NEW ZEALAND, SWEDEN AND THE UNITED STATES

Anthony Fetherstonhaugh, John Happs and David Treagust

INTRODUCTION

Science educators have continued to show interest in the identification and documentation of students' alternative knowledge frameworks as they relate to school science and learning outcomes. This interest has been highlighted in recent publications of science education journals such as the 1985 and 1986 volumes of Research in Science Education and conference proceedings such as Archenhold et al. (1980), Helm and Novak (1983), Jung, Pfund and v. Rhoneck (1981). Although there is ample scope and need for researchers to expose student understanding in many unprobed areas, science educators are already shifting their efforts toward the utilisation of established data in terms of instructional design.

The investigation reported here elicited views about the nature and propagation of light as identified by 13-16 year old students at one Western Australian secondary school. Initially, this paper considers the existing literature on children and adolescent understanding of light as reported from France, New Zealand, Sweden and the United States. Secondly, these documented understandings are compared with those encountered in Western Australia. The final aim of this study, which is not reported here, is to utilise this overseas and local information to plan instruction which takes into account student misconceptions to bring about conceptual change.

SOME PREVIOUSLY DOCUMENTED MISCONCEPTIONS ABOUT LIGHT

In a study conducted by Guesne, Sere and Tiberghien (1983) individual interviews and questionnaires were used to obtain information from 10-14 year old French students about the nature and behaviour of light. Results indicated that:

- Most 10-11 year olds and some 13-14 year olds considered light to be connected with its source or the effect produced. Light was not seen to exist between the two but "in the bulb" or "on the spot on the wall".
- Most children (11-14 year olds) thought that after light strikes a blank sheet of paper or a mirror, the light remained on those surfaces.
- Many children believed that light does not exist if not obviously perceived as a source of reflection.

The paper concluded that children do not use concepts systematically and that the particular situation determines the conception that is prevalent. The authors point out that children had a range of equally plausible ideas available to explain instances and did not recognize which, if any, was necessarily the "correct concept". Interviews and questionnaires were highly correlated with the interview providing a wider range of responses.

Stead and Osborne (1980) initially conducted individual interviews with 36 New Zealand students (10-15 year olds) who were questioned about their understanding of light via a number of line drawings depicting objects such as a candle, a heater and the moon. In a follow-up study a multiple-choice survey was used where the possible alternatives were designed to match the four major categories of response established in the preceeding interviews. The survey was administered to 144 students (12 year olds) none of whom had studied light in the previous 12 months, and to 235 students (13 students) who had recently studied a unit in light. Results indicated that children in the latter group held similar views to those who had not been taught light before and the following perspectives were common to both groups:

- Most children recognised that well known objects such as candles, torches, heaters, televisions and the Sun act as sources of light.
- Some children considered that light does not travel at all. Others felt that the distance travelled by light varied from a few millimetres to an infinite distance. Most children decided that the distance travelled by light depended upon whether it was day or night.
- Many students felt that light is only present if observable effects are witnessed, e.g., a spot of light on a wall.
- Some learners thought that seeing was an active eye process with something leaving the eye rather than light entering.

Stead and Osborne's study demonstrated that a reconsideration of students' prior knowledge is necessary for improving instruction. Students may need to be taught explicitly that light travels, how we are able to see and exactly what sources of light actually do.

Karrqvist and Anderson (1983) surveyed over 500 students (12-15 year olds) in Swedish comprehensive schools using problems involving: car headlights shining down a straight flat road; people seeing objects; refraction of light in a bucket of water and a torch covered by a piece of red glass. Students were asked to draw and explain the answers and Karrqvist and Anderson concluded that:

- Most students did not accept the model of light as involving propagation in all directions with light travelling an infinite distance.
- The teaching of optics in schools had little inpact in terms of the majority of students understanding the basic concepts abouth light.
- The idea of a "visual ray", i.e. something being emitted from the eye, was common amongst students.

Karrqvist and Anderson drew parallels between the learner's struggle to understand the nature and propagation of light and the historical growth of ideas about light.

Eaton, Harding and Anderson (1985) gave diagnostic tests to several hundred non-science major college level students in Michigan to probe their understanding about reflection, refraction, colour and vision. Amongst the key findings were:

- The nature of light can vary according to the environment.
- An individual's eyes see the shape of an object.
- Shiny objects reflect more light than dull objects.
- Colour is a property of objects, e.g., the book is red.

Eaton et al. (1985) also made reference to historical notions about light and the influence on thinking of everyday language such as "You are blocking my line of sight". A teaching module was composed of materials designed to be used by the teacher to effectively overcome the critical barriers to student learning. This module included the identification of student difficulties using a diagnostic test, and approaches to create student dissatisfaction with naive conceptions and to teach scientific thinking as opposed to remembering facts and to provide opportunities for application and practice.

Golberg and McDermott (1983) interviewed 90 students enrolled in introductory physics courses at the University of Washington. Interviews dealt with image formation in mirrors and lenses with each respondent being asked to make predictions and offer explanations about specific instances involving objects, lenses and mirrors. Many students thought that:

- The image of a rod placed in front of a mirror would move to the right if they moved to the left.

- They would be able to see more of themselves in a mirror by moving further away.
- The image of an object could be projected onto a screen without a lens.
- Half covering a lens would result in half an image being formed on a screen.

The data from these five studies provide a picture of students' understanding of a variety of concepts about light and its properties which is consistent between different countries.

A STUDY FROM WESTERN AUSTRALIA

One method of gathering information about students' misconceptions in science areas has been through individual interviews such as the Interview-About-Instances (Osborne and Gilber, 1980); the Interview-About-Events (Schollum and Happs, 1982) and Predict, Observe and Explain (White, 1982). Such elicitation techniques may be deemed time-consuming for the classroom teacher and difficult for an untrained person to use. Other method involve pencil and paper tests such as those above described by Stead and Osborne (1980), Karrqvist and Anderson (1983) and Eaton et al. (1985).

The study reported here involved one classroom teacher concerned with ultimately developing a teaching strategy based on students' understanding about light. Thus, a more expedient technique of data collection about student ideas was seen to be a needed prerequisite to this teaching. Subsequently, a multiple-choice plus reason instrument was developed to allow students to provide reasons for selecting particular responses to questions about the nature and propagation of light. The instrument comprised twelve multiple choice items (1-12) each with four distractors and four open response questions (items 13 to 16). Cartoon representations of some instance to do with light and its properties provided the intial stimulus. Items were chosen so that responses elicited could be compared with results reported in the literature. Some items were derived from the literature while other were original. The key question and/or topic being addressed by each item is present in Table 1.

The year 8, 9 and 10 students were grouped in unstreamed classes and represented a random sample in one high school of 500 students in an outer metropolitan area of Perth. Year 11 students were in two separate physics classes and could not be considered representative of the Year 11 population at that school. The instrument was administered in normal science lessons and most students completed the test in 35 minutes. Students were encouraged to ask about any questions or instances that were unclear in the instrument. Few enquiries were received. Students were requested to explain their reasons fully at the end of each question. Data from the test were analysed according to

TABLE 1

Topic or Instance used in the Light Conceptions Test
and Source of Original Item

Item Number	Topic/Instance	Type[a]	Source
1	How far does light travel during day?	M C	Stead & Osborne
2	How far does light travel during night?	M C	Stead & Osborne
3	Nature of images	M C	Stead & Osborne
4	Can images be in two places?	Int	Golberg & McDermott
5	Nature of Images (reflection)	Int	Golberg & McDermott
6	Are lenses necessary for images?	Int	Golberg & McDermott
7	Is all the lens necessary for an image?	Int	Golberg & McDermott
8	Light is necessary for seeing - humans	M C	Fetherstonhaugh *et al.*
9	Light is necessary for seeing - cats	M C	Fetherstonhaugh *et al.*
10	How far does light travel?	Int/ writ.	Karrqvist
11	How do filters work?	Int	Eaton et al
12	How do we see coloured objects?	Int	Eaton et al
13	Light reflecting from a mirror, frosted glass, clear glass & wood.	Int	Eaton et al
14	How do we see?	Int	Eaton et al
15	Why do black objects look black?	Int	Eaton et al
16	How does light help us see?	Int	Eaton et al

Note: [a] M C - multiple choice item;
Int - interview item
Int/writ - interview followed by written item.

the percentage of correct responses for each year level to enable a comparison of understanding between year levels and misconceptions were identified for each year level. Details of student responses to each item in the test are reported by Fetherstonhaugh, Treagust and Happs (1987).

SUMMARY OF RESULTS AND DISCUSSION

In this dicsussion, we present a summary of the findings of the Western Austalian research under five subheadings and these findings are compared with the results of the aformentioned studies conducted in France, New Zealand, Sweden and the USA.

Distance travelled by light

Significant numbers of students in the Western Australian study believed that light does not travel at all under certain conditions (19%, 9%, 29%, 7% held this belief in Years 8,9,10,11 respectively) whilst a similar number believed that light can travel variable distances. Most Year 11 students (93%) considered that light will travel until it strikes an object but most Year 8-10 students believed that only if a room is dark will light travel until it strikes an object. Students appeared to believe that the distance travelled by light is dependent upon the perceived brightness of the light; reasoning linked brighter light as being stronger light which is harder to stop and therefore capable of travelling a greater distance. Many students (33%, 35% 26%, 13%) considered that light from a car's headlamps would only travel 400m or as far as the person looking at the headlamps. A similar number of students (30%, 34%, 21%, 9%) thought that the distance light travels is dependent upon its energy. Karrqvist and Anderson (1983) reported similar figures in that not more than 30% of Year 9 Swedish students were familiar with the key idea of light propagation. Similarly, Stead and Osborne (1980) reported comparable data about students' ideas of the distance that light travels.

Reflections in mirrors

Items dealing with reflections in mirrors exposed similar views about light with students asserting the light would stay on the mirror or travel a variable distance. These perceptions were also documented in studies by Stead and Osborne (1980), Guesne et al. (1983) and Karrquvist and Anderson (1983).

Image formation in mirrors

Items dealing with the image formation in mirrors revealed that many of the Western Australian students (59%, 66%, 53%, 37%) were unable to correctly locate the images in mirrors and students' reasons for their choice suggested that they thought that an image existed in the mirror but can be screeened by an object. A large number of students could not provide a correct explanation about the location of images in mirrors. Goldberg and McDermott (1983) reported that about 50% of university students surveyed considered that images in a mirror could be in a number of places at the same time. the majority of the Western Australia students (70%, 83% 88%, 84%) thought that moving away from a mirror would lead to a more complete image and reasoned that in moving away from a mirror, a person or image gets smaller. Goldberg and McDermott (1983) reported that 90% of their sample of university students believed the same idea and that this view largely persisted (70%) following instruction.

Image formation by lenses

The items which dealt with image formation by a lens produced responses indicating that many of the Western Australian sample believed that a lens is necessary to form an image (42%, 52%, 41% 53%) with approximately the same number believing that an image would form on the screen if the lens were removed. These findings compared with Goldberg and McDermott's study which reported that most students thought that removing the lens would sharpen the image more. To fully understand image formation in lenses students need to be aware that light leaves in all directions from all points of the object and that light strikes every point of the lens which being curved is capable of forming an image even when the top portion is covered. While it is perhaps unreasonable to expect Year 8 and 9 students to be familiar with these concepts about the nature of light and lenses, incorrect ideas were also held by Year 10 and 11 students who had recently studied light in school. Goldberg and McDermott (1983) also reported that most students predicted that half the image would disappear when half of a lens was used to form the image.

Light is necessary for vision

Two items probed student's understanding that light is a necessary condition for animals to see and most Western Australian students (77% , 61%, 94%, 93%) considered this to be true for humans, although many students (70%, 70%, 47%, 20%) considered that cats are able to see in total darkness.

This study found that students' misconceptions have occurred at about the same frequency as recorded misconceptions in previous studies. In addition other misconceptions were identified. Most students did not use the key ideas of light to explain phenomena. Generally it was found that instruction has had little effect in altering misconceptions although Year 11 physics students had less misconceptions than did other students. Interviews are needed to examine students' frameworks in greater detail.

IMPLICATIONS FOR TEACHING

In science teaching we generally try to give students experiences of natural phenomona. However, most students have had experiences of many natural phenomena and have formed their own explanations for their observations. In many cases, for example as in the reasons offered in this study, students' ideas are incorrect and persistent. Consequently before attempting to teach about light teachers need to be aware of student's ideas about light and its properties. It is no use attempting to teach a student about persistance of vision if the student does not realise that light has to enter the eye before seeing can occur. A related teaching concern is that student's ideas are not consistent across a range of instances (for example, they believed that the distance light travels depends upon whether it is day or night) and appear to depend upon the context in which the basic idea is placed. This means that a teacher will need to be aware of the particular ideas students may use and will need to have a method of diagnosing those ideas.

The role of everday language is important when teaching about light, and teachers usually use a mix of everyday and scientific language in an attempt to communicate ideas in science classrooms. Given thirty students in a class, a multitude of meanings could be attached to the teacher's words. Everyday statements such as "my line of sight is blocked", "I'm using blue chalk" all serve to reinforce incorrect ways of thinking about light. Hence teachers need to be precise in their use of words and to define words carefully.

One alternative teaching approach is to use student-student interactions to bring about dissatisfaction with students' misconceptions in a given situation. However, students need to have many successful experiences in using new scientifically acceptable conceptions in a range of situations before becoming confident and familiar enough to use them regularly in place of their own ideas. The development of a teaching approach to help students address their misconceptions and bring about conceptual change is an ongoing focus of our research.

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SCHOOL PHYSICS AS TECHNOLOGY IN CHINA DURING THE GREAT PROLETARIAN CULTURAL REVOLUTION: LESSONS FOR THE WEST

Roger Cross, Ronald Price

INTRODUCTION

The Great Proletarian Cultural Revolution in China, variously dated from 1965-69 or 1965-76, was a period of social upheaval on a vast scale.

This period in education in China is of undoubted interest for teachers in the West because of the way in which Chinese curriculum writers appear to have attempted to produce textbooks that stressed the relevance of science rather than its theoretical aspects. The present writers believe that there is much that we can usefully learn by a critical examination of just what was attempted. We believe this particularly because of the present state of physics education in Australia, a state of declining interest below and growing appreciation of the relationship between physics, technology and social problems from above.

Situating the Textbooks

From the 1920 to today secondary schooling in China has been divided into a junior and senior school, consciously modelled on the 3:3 pattern of the USA. While the junior secondary school (*chuzhong*) has almost always been three years the senior secondary school (*gaozhong*) was reduced to two during the Cultural Revolution. Junior secondary school has, under the People's Republic, become almost universal in the cities, but has remained until recently a distant goal for much of the rural areas where as much as eighty per cent of the population live. Relatively few have continued to senior secondary school and beyond.[1]

The physics course examined was for junior secondary school students of ages ranging from about 12/13 - 15/16 years. Volumes 1 and 2 were published in 1972 and volumes 3 and 4 in 1974 in Yunnan Province. During this time, while reflecting nationally approved syllabi, textbooks were edited at the provincial level.

What is immediately apparent from an examination of the contents of the four physics books (Appendix 1) is the emphasis on useful knowledge rather than understanding of laws and principles. In examining the texts in some detail it is important to consider questions such as:

- What are the 'needs', in terms of physics education, of a population that is 80 per cent rural based?
- Does the course provide adequately for a largely rural population while providing a basis for further study at the senior high school level? What is the relationship between relevance and sytematic study?
- Does the course provide practical 'hands-on' experiences to back-up theory?
- Are the problems associated with the introduction of technology, especially motor vehicles and electrical appliances, into a developing economy considered?

DISCUSSION

Work on friction in this course is highly relevant and demonstrates ways in which an understanding of this resitive force has resulted in technological changes to bearings:

> There is friction between the axle and the axle bush. It wears out the axle and we have to use greater and greater force to pull the cart. A way to reduce friction is to use a bearing instead of a bush. When the turning speed is high such as on bicycles or machines, bearings must be used. Volume 1 Part: pp. 12-13

What is immediately apparent is the lack of experiments, and this fact raises some fundamental problems. What could a physics as technology course provide other than simple 'pulling apart' and 'putting together' of the artifacts of technology on the one hand or traditional physics experiments to illustrate the technology on the other? This physics course, though it provokes our thought, certainly does not resolve these problems.

The treatment is very thorough, both the positive and negative attributes of friction are explored and the usual Mao Zedong quotation adds weight to this aspect of study:

> We must learn to observe issues thoroughly, we should not only see the positive side but also the negative side of the issues. p. 12

Chapter 3 Volume 1 is entitled, Mechanical Transmission. It is perhaps the most unusual topic in the entire course and is not a topic found in Western physics textbooks. In China, a country which is in the throes of an industrial revolution it does have some merit. Many small engineering works and repair shops are scattered about the country and the majority of these are running machinery which requires the transfer of power. Certainly the efficient transfer of power from source to the point of work was very much a concern of mechanics. Various forms of transmission are considered:

> When belt driving is used, the turning of the motor can be transmitted to a machine which is quite far away from the motor. For example, belt driving is used to drive pumps and threshing machines using diesel engines in the country. There are many advantages in belt driving: its low cost, simplicity and the fact that it does not transmit vibration from the motor to the working machine ... p. 50

The advantages of gear transmission are then considered along with the various configurations of axles i.e. parallel for straight gears and at right angles for bevel gears. Knowledge of gear transmission is further developed:

> Suppose the driving gear has Z_1 teeth and turns at n_1 rpm; the driven gear has Z_2 teeth and turns at n_2 rpm. The number of teeth of the driving gear that pass the point where the two gears meet is Z_1n_1, and for the driven gear Z_2n_2. Driving a certain period of time the number of both gears that pass the point where they meet must be equal: therefore $Z_1n_1 = Z_2n_2$ p.52

It would be interesting to discover how many adolescents in the West know how the power is transferred from the engine of a motor car to its wheels or from the motor of a washing machine to the agitator in the washing compartment.

In defence of power transmission as a valid area of study we would point out that the problem of efficient power transmission:

1. has been one of continuing development by technologists from the beginning of human civilization. Belts, chains, levers, gears, shafts and hydrolics have all played a part;
2. could be used as a focus for problem solving activities. For example, gears not only transmit turning, but also convert turning into movement in a plane;
3. occurs in an 'unseen' way in many of the artifacts found in an around the homes of most students, examples are sewing machines, beating and whisking machines, power can openers and lawn mowers.

Although this section is nearly devoid of systematic theory the appropriateness of the cognitive level and the evident usefulness of power transmission devices coupled with the opportunites it gives for setting problems to enhance creative thinking make this topic attractive and worthy of consideration by curriculum planners in the West.

Electricity is a vital source of energy, and in a country undergoing a rapid industrial revolution is a precious resource which must be used economically. The size of the population is such as to suggest that electrical generation may well be one of the limiting factors to rapid modernization.

> Electricity meters are installed where electricity is used. Its function is to automatically record the power consumed. The calculation of the electricity used is: take the figure at the beginning of the month from the figure at the end of the month and the difference is the amont of electricity consumed. For instance, reading at beginning of month = 1467.5 Kw and at the end of the month 1492.8 Kw. Therefore the amount used = 25.3 Kw. 1 Kwh of electricity can produce 14 Kg of nitrogeneous fertilizer ... We must carry out Mao Zedong's instructions, "to save to make the revolution and build socialism swiftly and economically". Volume II p.31.

This section continues with examples showing how electricity can be saved. Conserving energy sources is clearly an important issue in China and students' attention is drawn to the wasteful consequences of the indiscriminate use of electricity. There are lessons here for the West, the small percentage drop in consumption that might result from a science unit on conservation of energy resources might pay great dividends in energy savings.

The first twenty-two pages of Volume II are devoted to the normal topics which make up a standard introduction to electricity. Our criticism of this section concerns the depth of treatment. This raises a number of interesting questions including the calculations of the overall resistance of a circuit containing resistances in parallel. It appears that the Chinese curriculum writers have deliberately gone out of their way to introduce sufficient theory to enable the many practical applications, such as lighting circuits, to be discussed, but in so doing may have introduced a depth of treatment beyond the average student at this age level.

Along the same general theme of social responsibility Volume II also deals with electrical safety, and the maintenance of lighting circuits. Although we in the West might be appalled at the thought of students being encouraged to maintain lighting circuits, the principles of applying concepts to useful and relevant human needs is worth very close examination. And with regard to the maintenance problem, in a society where skilled electricians are to be found only in large centres of population and the youth represent the only knowledgeable group it would possibly be preferable for students to be involved in this work rather than their parents!

A number of topics are specifically aimed at students in the rural sector. For example:

1. Mini-hydroelectric power stations in the country, (Volume III pp.29-54)

There are a very large numbers of low Kw output hydroelectric power stations in the mountainous regions of China. The importance of these installations can perhaps be gauged by the fact that approximately one half of Volume III is devoted to giving students an insight into what they look like and how they work. Certainly the presentation is descriptive and appears to fall between the two stools theory and practical detail. Insufficient theory to understand the interconversion of the energy forms and an undersinding of how electricity is produced in a generator on the one hand and on the other details concerning their operation which might be given to an operator on the other reduce the value of this section. The inference here is a desire on the part of the curriculum writers to place 'power' in ordinary peoples' hands rather than elite technocrats. This was clearly one of the aims of the Cultural Revolution and is, in our opinion, a major problem confonting the West where increasingly more and more artifacts of technology are of the 'black box' variety, accessible only to experts.

2. Broadcasting by wires and general knowlede of radio, Volume II, pp.103-135 and Volume IV, pp.23-63.

In the commune period (1958-80) many production brigades ran stations broadcasting over land lines. Music, news, moral-political education and production information and instructions thus reached the peasantry in their homes and in the fields. In the cities large factories and other institutions had similar installations. It is therefore not surprising to find material on the physics of these installations in the textbooks. This part of the course has all the hallmarks of a normal physics syllabus. The principles of microphones and speakers are covered in detail. But in addition students learn how to wire-up a broadcasting network of speakers linked to a central amplifier (figure 1).

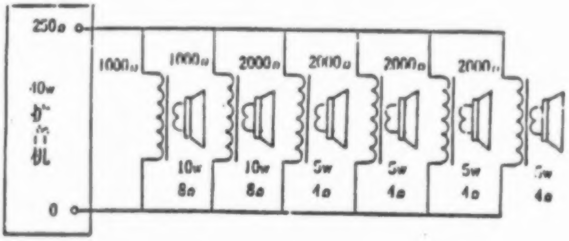

Figure 1. Example of Broadcasting Network. Volume II pp.103-135 and Volume IV pp.23-63.

CONCLUSION

The Great Proletarian Cultural Revolution was a complex period whose history will be debated for a long time to come. The present Communist Party and government leaders have rejected it completely, emphasizing all the violence and anti-educational things which occurred. Careful examination of some aspects, such as the textbooks we have analysed above, would suggest that this could be to reject much that is of fundamental importance, and not just for China alone. Our analysis has shown how the course ensures that students are familiar with some of the important ways in which industrial and agricultural technology were being utilized.

In this way the textbook editors were conforming to the guidelines of the Cultural Revolution to justify their choices. Combining education with productive labour was a major slogan, together with 'qifa', an expression which means teaching to stimulate active, thoughtful participation in contrast to traditional 'goose-stuffing' methods.

To sum up, let us return to the questions we asked above. Firstly, do the textbooks meet the needs of the eighty per cent of the populationn who live in rural China? The great majority of the children in these areas will not continue school beyond the junior secondary grades, if that. Their needs, therefore, would seem to be an understanding of the technology surrounding them in their daily lives. Whether the course as it was structured, consisting of descriptive accounts could develop the thinking and practical skills which contemporary slogans demanded is another matter!

Secondly, do the textbooks provide a basis for that tiny minority which may go on to higher studies in physics? They certainly do not set out to provide a physics experience that has traditionally been considered a foundation for further study. But outside China all is not well and there have been increasing calls in recent years for a more relevant science experience which would take account of the relation of science, technology and society generally (Fensham, 1981; Yager, 1982 and Markle, 1982). We certainly believe that it is possible to provide a basis for further study while at the same time catering for the majority who will not be continuing their physics education. One way towards this goal is through the linking of physics with the technologies found in and around students' homes.

Third, there is the question of the provision of 'hands-on' practical experiences. Chinese teachers, probably from a combination of traditional, Confucian, rote-learning methods of learning and the reality of poverty and lack of apparatus, have made practical work a rare feature of science teaching in the ordinary schools. This was criticised in an important speech by Wan Li at the National Education Conference in may, 1985 (Wan Li, 1985). The textbooks seem in this respect to fail both the goals set by the Cultural Revolution and those of the Chinese government today.

Finally, the curriculum adopted by a society reveals much about its norms and priorities. In another paper we have explored the way in which moral-political values influence school science courses, both in China and the West (Price and Cross, 1987). The books we have examined here clearly reflect the Cultural Revolution stress on the lives and needs of the working people

NOTE 1

A recent book has suggested for major cities a figure of seventy per cent of primary graduates going to junior secondary and seventy per cent of junior secondary graduates going on to senior (Rosen in Hayhoe, p.79).

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APPENDIX 1

The Junior Middle School physics course for the Yunnan Province, 1972-1974 edition:

CONTESTS

VOLUME 1

PART 1: MECHANICS 1
Chapter 1: Motion and Power 1
1. Speed of things 1
2. Power 4
3. Gravitation and elasticity 6
4. Friction 10
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2. Levers 24
3. Pulleys and principal of work 30
4. Inclined plane and efficiency of machines 34
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3. Use of electric motors 91
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7. Calculations of actual circuits 25

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2. Heating effect of current 33
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5. Maintenance of lighting circuits 47
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7. Safety in electricity 51

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Chapter 3: Electricity Generation and transmission 57

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Chapter 7: Mini hydroelectric Power Stations in the Country 29

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DRAWING TOGETHER TEACHING METHODS AND STRATEGIES INTO A MODEL FOR SCIENCE EDUCATION

Rod Francis

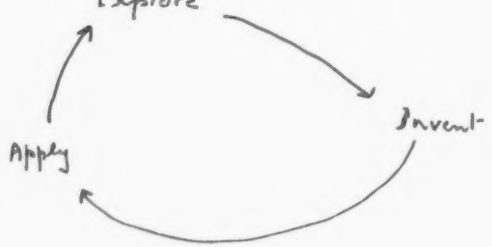
Teacher educators and other involved in inservice work, face the problem of developing teachers who are able to incorporate research into classroom practice. These problems have been recently referred to findings by Hill et al (1986) and Tisher (1987).

Teachers find it hard to change their practice. The process of incorporating change is particularly difficult when new ideas are not expressed in appropriate language (Olsen, 1980).

The purpose of this paper is to describe a model for structuring and sequencing learner experiences and to report on the outcomes of using this model. The model used in this piece of action research incorporates, previous ideas in science and mathematics proposed by Karplus (1977) (Figure 1) and Wilson (in Cooper et al, 1984). Research findings in a number of new areas such as cognitive learning, curriculum development, teaching strategies and childrens alternative frameworks have also been incorporated into this model.

FIGURE 1

The Karplus Learning Cycle



THE MODEL

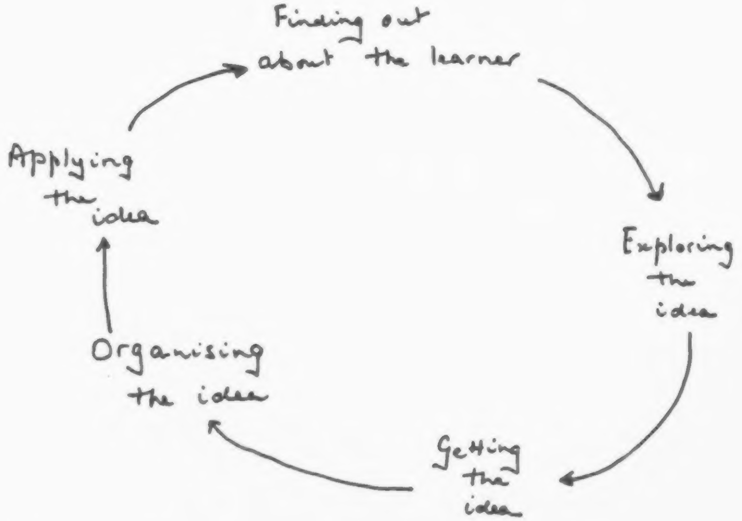
If a teaching model is to be useful it must be:

1. clearly described in terms which teachers can understand.
2. comprehensive and flexible enough to accommodate most teaching situations and topics.
3. able to provide clear guides for appropriate learning activities.
4. able to identify appropriate behaviours for both the teacher and the pupil during the sequence, and be
5. able to draw together up to date and current ideas on teaching and learning in science.

FIGURE 2

An expanded five stage learning cycle

(after Hill et al, 1986)


Finding out about the learner
Exploring the idea
Getting the idea
Organising the idea
Applying the idea

The model is outlined in Figure 2 and briefly described in Table 1. It has some common elements with previous learning cycles but different in several ways in that it:

a) uses simple language.
b) describes the purpose of each stage.
c) outlines some learning strategies typical of each stage,
d) recognizes the changing role of the teacher and learner in the learning process, and
e) incorporates recent findings of research in teaching and learning.

RESEARCH AND PRACTICE

The following is a resume of some of the current research areas which have been drawn together in the new learning cycle in the, 'finding out about the learner' and 'organising the idea', additional stages to the earlier Karplus cycle.

A. Finding out about the learner

1. The area of conceptual frameworks or misconceptions in science education has had considerable prominence in recent years. The works of people such as Champagne et al (1983), Driver (1981), and Osborne & Freyberg (1985) have illuminated the way in which children develop ideas to explain phenomena. Techniques by Osborne and others have provided tools for classroom teachers to explore the development of children's ideas.
2. Children's attitudes and feelings towards science are extemely important. Recent work by Fraser & Fisher (1982) and others has shown that values and feelings are so interwoven with concept acquisition and concept development that it is imperative for teachers to be sensitive to this area within their student groups. In particular the work on girls in science by researchers such as Kelly (1981) Manthorpe (1982) demonstrates clearly that many girls have a different "in-point" to science and traditional starting points are inhibitors to many girls. Similar studies on different cultures and Aboriginals clearly demonstrates differences in this area among students.
3. Language use as both the means of understanding and describing the world and ideas. Driver (1985) and Osborne & Freyberg (1985) clearly illustrate the need to look at childrens own language and the problems associated with the duality of everyday words and the use of the same words in science. Perhaps fundamentally more important, is the notion that science is a culture with its own cultural values and language (Hill et al 1980). We in science education could do well to look at the area of ESL research on cultural heritages and the problems of people, learning in the context of another culture (Brown, 1980). It may give use insights into bringing students within the "culture" of science. The implication is that while students may

track two sets of ideas (their own and science's versions), these ideas may well not be rooted just in a purely conceptual double track as reported in the literature (Osborne & Freyberg, 1985) but includes a whole language/cultural/values, double track.

B. Organising the Idea

This stage is about providing learning environments to assist students to construct new schema which provide them with an ability to:

a) identify examples and non-examples of the new idea,
b) link new ideas with previous ideas to develop a more powerful way of thinking about things,
c) develop confidence and security with the new idea,
d) provide time for assimilation of the idea within existing schema and
e) reflect on knowing how they know about the new idea.

This stage draws on the meta-cognitive research within the cognitive phychology area and ideas on the role of knowledge. For example Glaser (1984) explained the idea of the acquisition and preservation of new schema and the ability of such schema to provide a means of commanding a large amount of specific information. The work on developing learning models by researchers such as Osborne & Wittrock (1985) and Rowell & Dawson (1985) have helped link theory with classroom strategies to assist the process of development of new schema.

The work of Baird (1986), Baird & Mitchell (1986) and Baird & White (1982) is beginning to provide types of strategies for helping learners think about their own learning, a vital part of this stage of this learning cycle.

Lee (1985) and Lee & Fensham (1987) have provided evidence that students who have knowledge stored in a more associated way, solve problems more often than those who have less associated knowledge. This mapping and monitoring of their own concept development provides further learning strategies for assisting students in "organising their ideas".

Research Evidence for the Use of Learning Cycles

There is considerable research evidence indicating the value of learning cycles in producing desired learning outcomes. Early work by Ward & Herron (1980) and Schneider & Renner (1985), Abraham & Renner (1986) and Tindall (1985) have provided quantative and naturalistic data to support long term retention and development of ideas and student preference for learning in this way. Such research which supports this teaching model has provided a base on which to refine and develop the 5 stage model outlined in this paper.

The role of questioning and its role in student thinking, drawn together by Elstgest (1985) and supported by Mitchell & Baird (1985) provides evidence for the changing role behaviours for teachers and students at different stages of learning. This is reflected in the description of the phases of the cycle outlines in Table 1.

Action Research: outcomes of using the model in a pre-service education program

The model described above has been used as the central focus for a number of mathematics and science subjects in the K-6 teacher preparation program at RMIHE.

Walker (1985) has described action research as a process of gathering data about the outcomes of an attempt to improve a situation. It involves the collection of both qualative and quantative data from participants in the innovation.

In general the data collected during 1986 and 1987 has provided support for the use of the learning cycle for structuring learning in pre-service programs and for its use by trainee teachers in designing teaching units for schools.

Action Research with Teachers

Following considerable experiences of using the model with trainee teachers, it is now being used collaboratively in teacher/curriculum development programs in schools. Results of this work have been summarised by Redden (1987). He reported that teachers claimed:

a) we are much more sensitive to our own behaviours and the pupils learning behaviours,
b) we are able to monitor in a more significant way the development of the children's concepts and ideas,
c) children work more in groups and discuss and express their ideas more freely,
d) we have an increased sensitivity to childrens language and feelings and how they relate the children's learning and
e) we feel much less a prisoner of new curriculum materials and ideas - we can analyse them in terms of the learning cycle and incorporate them within our classrooms.

CONCLUSIONS

It is time to provide a synthesis of ideas in Science Education. Tisher (1987) has asked - do the results of research inform practice? In this paper a learning cycle has been outlined which draws on recent areas of research and linked it to existing cycles to provide an extended and refinded model for classroom practice.

The synthesis of these ideas provides two important outcomes:

1. an effective working model for teachers, and
2. a situation in which students can not only say, "I can do it" or even "I know I can do it" but more importantly "I know how I know".

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INDIVIDUAL DEVELOPMENT DURING TEACHER TRAINING

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In this paper, one aspect of the initial phase of a three-year project on the teaching and learning of science in schools is described. The project seeks to increase understanding of the processes and mechanisms of teaching and learning through intensive observation, participation, and reflection.

Classroom teaching and learning are influenced by many things - in fact, the breadth and diversity of factors which bear on teaching and learning sometimes seems bewildering. For teachers, what is taught, how it is taught, and how well it is taught are all outcomes of a continual process of conscious or subconscious decision-making. These decisions are influenced by factors associated with the teacher, the students, the content under study, and the classroom, school and societal context. Similar conditions operate for students and their learning. The focus of this paper is limited to only some of these factors - those which are, or those which bear directly on, intellectual attributes of the teacher in training. However, as will become clear, even these factors are complex in their nature and manner of interaction.

Among other things, how a person teaches a given topic is influenced by his or her present intellectual competence with respect to this topic. As defined here, intellectual competence comprises a number of cognitive and affective factors in four main areas: Attitudes (including Values and Concerns); Perceptions; Conceptions (including Knowledge and Beliefs); Abilities. Each of the areas of intellectual competence influence one another. A person's intellectual competence will influence subsequent intellectual performance as he or she plans or teaches a lesson on the topic. By intellectual performance is meant the person's Attitudes (expressed verbally or non-verbally), Perceptions (e.g. awareness of the extent of student understanding, or development of the lesson in terms of the lesson plan), and Decisions and Behaviours about what to do and why, as the lesson proceeds.

The purpose of this paper is two-fold: to highlight the nature of some interactions which occur among the different areas of intellectual competence, and the influence of these interactions on intellectual performance; to argue for a style of research on teaching and learning which, by acknowledging these interactions and their importance, has the potential to deepen understanding of the mechanisms by which teaching and learning operate.

In this paper, one group of participants in the project will be considered - a group of fourteen science graduates in the first twelve weeks of their one year preservice training for secondary school science teaching. Information on these students is set out in three main sections below. One major aspect of context (the nature of the preservice course being undertaken by the students) is not considered here.

THE INTERACTION BETWEEN CONCEPTIONS AND ABILITIES, AND THEIR EFFECT ON INTELLECTUAL PERFORMANCE

In this section, aspects of the conceptions and abilities areas of intellectual competence will be inferred from students' performance in two episodes which occurred during individual interviews at the beginning of the study. In both episodes, many students exhibited faulty performance which is attributed to conceptual and processing inadequacies.

EPISODE 1: CARTESIAN DIVER TASK

The Cartesian diver task formed part of an extensive interview held with each student in the week before the start of the course. These interviews typically lasted between one to two hours. For the task, each student was asked to manipulate the apparatus and to answer two inital questions: 'What do you see happening?', and 'Why do you think it happens?' Particular responses were followed up through diagnostic questioning. Subsequently, students were asked about the extent to which they were satisfied with their explanation, how they would go about testing it, and whether they could think of any 'real world' examples of a similar effect. Full transcripts of the episode were prepared and analysed.

In 1982, Baird and White reported seven 'deficient learning tendencies' which had been identified with three tertiary biology students. These tendencies were processing habits which militated against learning with understanding by limiting the person's metacognitive awareness and control of the task. Such tendencies from part of the abilities area of intellectual competence. Of these seven tendencies, each of the six which are relevant to the current task were observed. The incidence of each of these tendencies for the fourteen students is shown in Table 1.

TABLE 1
Incidence of deficient learning tendencies during the Cartesian diver task

Tendency	Short Description	Number of Students exhibiting tendency
Related to Critical Observation		
Superficial attention	'Skimming' - uniform lack of attention to the task	9
Impulsive attention	'Spotty' attention - attention to certain parts to the exclusion of other parts	3
Related to Logical Reasoning		
Inadequate monitoring	Lack of checking of progress, particularly the adequacy or internal consistency of responses	5
Inappropriate application	Attempting remembered procedures blindly	4
Premature closure	Premature decision to finish task when important aspects remain incomplete	3
Lack of reflective thinking	Includes lateral, creative, introspective thinking	
- internal	Lack of association or integration of present task with related content or experiences (includes failure to determine how to test explanation of observations)	11
- external	Lack of association or integration of present task with wider experiences e.g. those in everyday life	6

A striking feature of this task was the disinclination of students to observe carefully, and to base their explanations on these observations. Many students were content to theorise about causes for effects inadequately observed. This lack of faith in observation was related to both superficial attention and impulsive attention.

Superficial attention

Six of the fourteen students just didn't bother to look at the apparatus carefully enough. Thus, for most of the episode they didn't see the hole in the diver or changes in the water level within it.

Impulsive attention

For many students, observation simply served to test their ideas. Thus, these observations were limited, and yielded various results. Four other students placed even less value on observation. They believed that air must leave the diver through a hole, but they couldn't find a hole, and they didn't look for bubbles as the diver submerged.

Students also exhibited a variety of logical reasoning inadequacies related directly to one or more of the deficient learning tendencies in Table 1. Many of these reasoning inadequacies operated in conjunction with specific inadequacies concerning the concepts of buoyancy, amount, density, pressure, and volume. Assumptions based on these inadequate conceptions influenced the direction and quality of their reasoning.

For the whole task, the interviewer rated four of the fourteen students as having achieved a satisfactory explanation and understanding. Six students achieved a partial, although deficient, explanation. Of these six students, five were unaware of directly conflicting statements in their explanation. Four students were unable to make much progress at all. It is significant that only three students expressed satisfaction with their own explanation.

EPISODE 2: ENERGY TASKS

The second episode comprises a sequence of three tasks which sought the students' conceptions of energy. The three tasks were as follows:

Task A

The student was presented with 200 gram of each of four foods - carrot, potato chips, apple, and chocolate. The student was then presented with a hypothetical situation in which he or she was to eat the shown amount of one of the foods after each meal for the next two weeks. The food was to be consumed in addition to the normal food intake, and there was to be no other change in exercise or life style. The student was asked to choose a food, and then his or her conceptions related to energy intake, storage, and use were elicited by diagnostic questioning. Subsequently, the student was asked to predict and explain what would happen if he or she fasted for one month.

Task B

The student was asked to hit a copper plate with a hammer, and then consider the energy changes which occurred as a result of the hit. Responses were checked through a supplementary series of questions about a golf ball and club.

Task C

Three arrangements of ten dominoes were constructed in front of the student. These arrangements were a vertical pile, a random horizontal arrangement, and an ordered horizontal array. The student was asked whether the different arrangements have different energy.

Full transcripts were made of the fourteen students' responses, and these responses were then considered in terms of sets of key propositions, or accepted theory, related to each task. For example, for Task A, responses were considered in terms of thirteen propositions regarding mass and body functioning, twenty-three propositions regarding energy and body functioning, and one proposition regarding the non-interconvertability of mass and energy under these conditions. Through this analysis, specific conceptual and processing inadequacies were identified.

As for Episode 1, interrelationships among the conceptions and abilities components of intellectual competence, and intellectual performance, were discovered. Processing inadequacies, considered as deficient learning tendencies, and conceptual inadequacies were inferred from students' attitudes, perceptions, decisions and behaviours displayed during the tasks. Further, evidence was found whereby the interaction of conceptual and processing inadequacies during the tasks generated new misconceptions, and also changed personal attitudes and perceptions regarding the topics, tasks, and the teaching of energy. Major conceptual inadequacies were identified with respect to the nature and types of energy. Processing inadequacies related to four different learning tendencies were discovered. Each of these will now be considered briefly.

CONCEPTUAL INADEQUACIES

The different types of energy, and their nature

> 'Movement can be regarded as a type of energy - or, movement can be regarded as an expression of the energy, ... a demonstration of the energy being spent. If you see movement, you know energy is being used ... [a moving golf ball] has potential energy, because it is now higher than what it was, and it can fall, so energy is still being expended, but the golf ball itself doesn't have any more energy [than a stationary one], because it has expended that in initially moving - the movement came from the golf ball pushing against the club, and the force ... that it exerted on the club has been exerted, the [elastic] golf ball is in its original shape, and the expression of that push is its movement through the air ...' (Student 2)

This quote demonstrates the student's uncertainty about the relationship of the effect between different forms of energy, the nature of energy itself (is movement energy, is movement an expression of energy, or does movement have energy?), and its relationship with concepts such as momentum, force, and impact. The uncertainty about energy as an attribute (is), expression (evidence of), or component (has), extended to other forms of energy, e.g. 'glucose is energy' [cf. glucose contains energy] (Student 4); 'energy is stored as fat [cf. in fat]; the energy is the food itself' (Student 5); 'heat is not energy, it's a result of using energy' (Student 1).

A source of the confusion seems to be uncertainty regarding the relationship between types of energy in which motion is apparent (e.g. light, sound, electricity), and stored, static energy - energy in reserve, 'potential' energy. For example:

> S: [Student]: 'There is potential energy stored in the petrol, in terms of its chemical potential'
> I: [Interviewer]: Is that a different sort of potential energy from that [the gravitational potential energy]?
> S: Um ... well "potential" is pretty abstract - I supose, no. I define potential energy as when it is has the potential to become energy, be it sound, heat, kinetic, or whatever.
> I: Oh, so it means the potential to become energy?
> S: ... Potential energy is not immediately apparent before it's transferred, though ... electric energy is active energy ... I don't think I have a concept of energy myself - it's more a matter of intuition, as to whether you think it's energy or not - movement is a common factor ...
> I: What about potential energy?
> S: It's just that, it's not actually an energy, it's something that's potential, it doesn't exist.
> I: Would you say that the top domino has energy?
> S: Yes ... it has the potential to transfer energy - it can potentially move.'
> (Student 6)

The confusion with potential energy seems greatest with gravitational potential energy. Three students did not consider that dropping a body involves energy at all, but only gravitational force or momentum. In terms of stored energy, five students believed that energy is not stored as such in food, and three of these students believed that non-living things generally do not contain energy.

Non-conservation of energy

Five of the fourteen students did not conserve energy, e.g.:

> 'The energy is transferred into physical movement, or another energy-absorbing action. I guess you could say it disappears. Once the energy is used, it no longer exists ... it has been expended, and is now gone' (Student 2)

Interconversion of mass and energy

Together with non-conservation of energy, perhaps the most disturbing aspect of this episode with these fourteen science graduates is that, in Task A, six of them interconverted mass and energy. Perhaps this view arises from the common associations between mass and energy of the form 'chocolate has got more energy than the carrot, therfore I will put on more weight' (Student 1). However, the argument expressed by the six students all followed the following pattern: energy appears (is created) when bodily reactions occur with food molecules ('food is burnt'). Food doesn't have energy; energy appears as mass is destroyed. The reason why you lose weight when you fast is because you are converting it into energy, e.g.:

> I: 'Now, you're saying that you are using up your energy stores to gain energy for yourself?
> S: Yeah
> I: Now, you've also said that you are losing weight
> S: Yes, because this fat - the accumulated energy - is in the guise of fat, fatty deposits, and these fatty deposits are heavy
> I: And where do they go?
> S: They are used ... they've gone - you've used it up ...
> I: So you're saying, by your conception, a conversion of mass into energy?
> S: Yeah' (Student 8)

An extension of this view was a 'using energy, but not losing energy' argument for Task B. This view was held by three students. The view is that there is an interactive pool of body mass and energy. The body works to maintain equilibrium in terms of the energy level. So, when something is hit with a hammer, you do not end up losing energy, because your body converts some body mass into energy, in order to re-establish energy equilibrium.

PROCESSING INADEQUACIES

As may be inferred from the above quotes, various processing inadequacies were observed, involving inadequate monitoring, inappropriate application, premature closure, and lack of reflective thinking. These inadequacies resulted in muddled thinking and, particularly, a disinclination to think through a line of reasoning and evaluate its logical outcome. Students were aware of their difficulties:

> 'It's really hard for me to say what I know [compared with] what I remember from high school and therefore say I know, because if I say what I know, none of it makes any sense to me ... I try to answer your questions, so I rely on the things I learnt, and try to use them ... when it's not logical, I toss it aside, and try on my own - the only thing that's left [from school learning] is the big words that the emphasis was put on

> [e.g.] kinetic energy - to me, that's only a label that's given to movement energy - it doesn't mean I understand it ... Movement is energy - No, that doesn't sound right. No matter what example I use, I cannot say movement is energy'. (Student 1)

PERCEPTIONS AND ATTITUDES: THEIR INTERACTION WITH EACH OTHER AND WITH CONCEPTIONS AND ABILITIES

Various methods were used to determine students' perceptions and attitudes. The first author participated in all class activities through the nine weeks and shared with the students their experiences and reactions. Class observations, structured individual interview, informal individual and group discussion, questionnaires and student written evaluations were all used repeatedly. However, the most valuable source of information has come from student diaries. Throughout the course, students are keeping personal diaries, in which they regularly record feelings, thoughts, concerns and aspirations about themselves and their development. In these diaries, students give an honest appraisal of themselves and their experiences, knowing that the diary will only be seen by one other person (the first author), and that all entries are confidential.

The findings regarding students' perceptions and attitudes towards teachers and teaching, learners and learning, themselves and their competencies, their course of study, and so on highlight their highly individual nature and the complex interdependence between them and the other areas of intellectual competence.

SOME CHANGES IN INTELLECTUAL COMPETENCE THAT HAVE OCCURRED OVER THE PERIOD

As with the intial perceptions and attitudes above, it is not possible to document here the individual and complex changes that have occured in the intellectual competence of students over the period described. But change has occurred, particularly in attitudes, to, and perceptions and conceptions of, themselves and teaching. Experiences in the course have challenged all the students. Some experiences have stimulated an increased proficiency and, with it, confidence, while other have exacerbated uncertainty and apprehension. As the latter changes have usually been associated with enhanced realisation of themselves and the range and extent of demands of teaching, they have constituted a necessary stage in positive personal development.

> 'I'm finding the course very personal. I am starting to question my own self. This is sometimes very disturbing, because I ask a lot of questions that I always took the answers to for granted'. (Student 4, Week 2)

> 'The style of [a school supervising teacher's] teaching ... which I was essentially asked to present and which in hindsight I'm ashamed to admit I did without the slightest whimper of protest, is boring the kids to death'. (Student 10, Week 6)

> 'My attitudes have changed or are changing, but my personality is yet to reflect this'. (Student 12, Week 8

> 'I now know that I am quite capable of teaching children. My challenge now is to extrapolate that teaching skill to include learning methods which are enjoyable for students, and enthuse them'. (Student 9, Week 8)

Despite evidence in other studies for the supposed intractibility to change of such personality attributes as perception and attitudes, we believe that the above transcripts represent real evidence of such change.

DISCUSSION

The complexity of teaching is becoming increasingly acknowledged by educational researchers. This acknowledgement has necessitated a change in focus of research on teaching from behaviours to mechanisms, from effects to causes, from observations to explanations - in essence, towards meaning through study of process. In turn, this change in focus necessitates change in style of research, and the methods used (e.g. Erickson, 1986).

The style of research should preserve the ecology of teaching. How a person teaches can not be separated from why the person teaches this way. Understanding both the how and the why of teaching requires that research must be done where the teaching occurs. It must embrace the range of personal and contextual factors which operate to influence the teacher's decisions and the behaviours he or she exhibits.

The terms intellectual competence and performance have been used in this paper in order to emphasise this integrity of process and outcome. A person's competence to teach, say, Year 10 Electrical Energy is not determined by subject matter knowledge, or 'teaching ability', or some other factor taken in isolation. Teaching behaviours are inextricably related to current attitudes, perceptions and decisions made. Teaching performance is thus linked to established cognitive and affective elements of the person's intellect. Both teaching competence and performance must be considered in relation to the content being taught. Other factors, not considered in this paper, also influence the how and why of teaching, e.g. the students' learning competencies and performances, and the context in which teaching occurs, both within and outside the classroom.

The three-year project of which the content of this paper forms part is an attempt to embrace this complexity. Many of the trainee teachers in the group above will be followed through their first two years of full-time teaching. Other groups of currently practising teachers are also participating in the project. These groups are engaged in a style of collaborative action research, whereby they are researching aspects of their own teaching and their students' learning over a protracted period.

The holistic nature of this research presents obvious difficulties in generation and interpretation of data. But in the complexity of the undertaking lies its promise. To take one example related to some results presented above, the groups of trainee and practising teachers are currently researching the topic of energy in the science curriculum, using the methods of reflection on practice and collaborative action research. Over time, it is expected that their research will touch on many of the areas of intellectual competence and performance above, all considered in relation to the content and context of their own teaching. Much is to be learned by both the teachers and the authors, but from this learning should come understanding. The endeavour merits the effort.

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HSC CHEMISTRY STUDENTS' UNDERSTANDING OF THE STRUCTURE AND PROPERTIES OF MOLECULAR AND IONIC COMPOUNDS

Bill Butts and Roland Smith

INTRODUCTION

This paper reports the results of an interview study which followed an earlier survey of 266 Year 12 chemistry students in ten Sydney and near-Sydney High schools to determine which concepts in the core section of the HSC Chemistry syllabus they perceived as most difficult (Butts and Smith, 1987). That survey indicated that concepts related to structure, dissolution processes and precipitation were considered to be difficult. The related items, as they appeared in the survey, and their rank order of perceived difficulty, are shown in Table 1.

ITEM	PERCEIVED DIFFICULTY	
	RANK ORDER*	PERCENTAGE**
The connection between solubilty and the formation of a precipitate.	8	30
The difference in properties between ionic compounds and molecular compounds	12	29
The difference between electrolytes and non-electrolytes (in terms of the presence of ions and molecules).	13	29

* Most difficult ranked as 1.

** The percentage of students who rated this item as 'very difficult' or 'extremely difficult'.

Table 1.

While other concepts, connections between concepts and skills were rated as more difficult by the sample, these three items were seen as of particular interest because of the interrelation of the concepts involved and the fundamental nature of these concepts for the understanding of chemistry. It was decided therefore, to follow up the survey with individual interviews of a sample of students from the schools surveyed. The results of these interviews would be used to construct paper and pencil surveys to diagnose student difficulties in understanding some of the relationships between structure and properties in chemistry.

PROCEDURE

The students for interview were selected according to their responses to the three survey items above. Those who rated these items as "very difficult" or "extremely difficult" were identified from the survey data and their schools were asked to arrange for them to be interviewed. The number of students selected to be interviewed from each of the ten schools varied depending on the size of the schools' Year 12 Chemistry candidature; the largest school provided 6 interviewees, the smaller schools only two. In total 28 interviews were conducted by the authors, who visited the schools for this purpose. Interviews were recorded on audiotape for later examination. In only four cases were the selected pupils not available for interview; in these cases substitutes who had been nominated as such by the researchers, were interviewed.

The interviews followed an "interview about events" protocol (Osborne, 1980), and were designed to elicit students' understandings of:

a) the structure of solids, especially the nature and relative magnitudes of interparticle forces;

b) the nature of the dissolution process and the nature of the resultant particles in aqueous solution;

c) how an electrolytic solution conducts an electric current;

d) why a precipitate forms in a reaction between certain ions in solution.

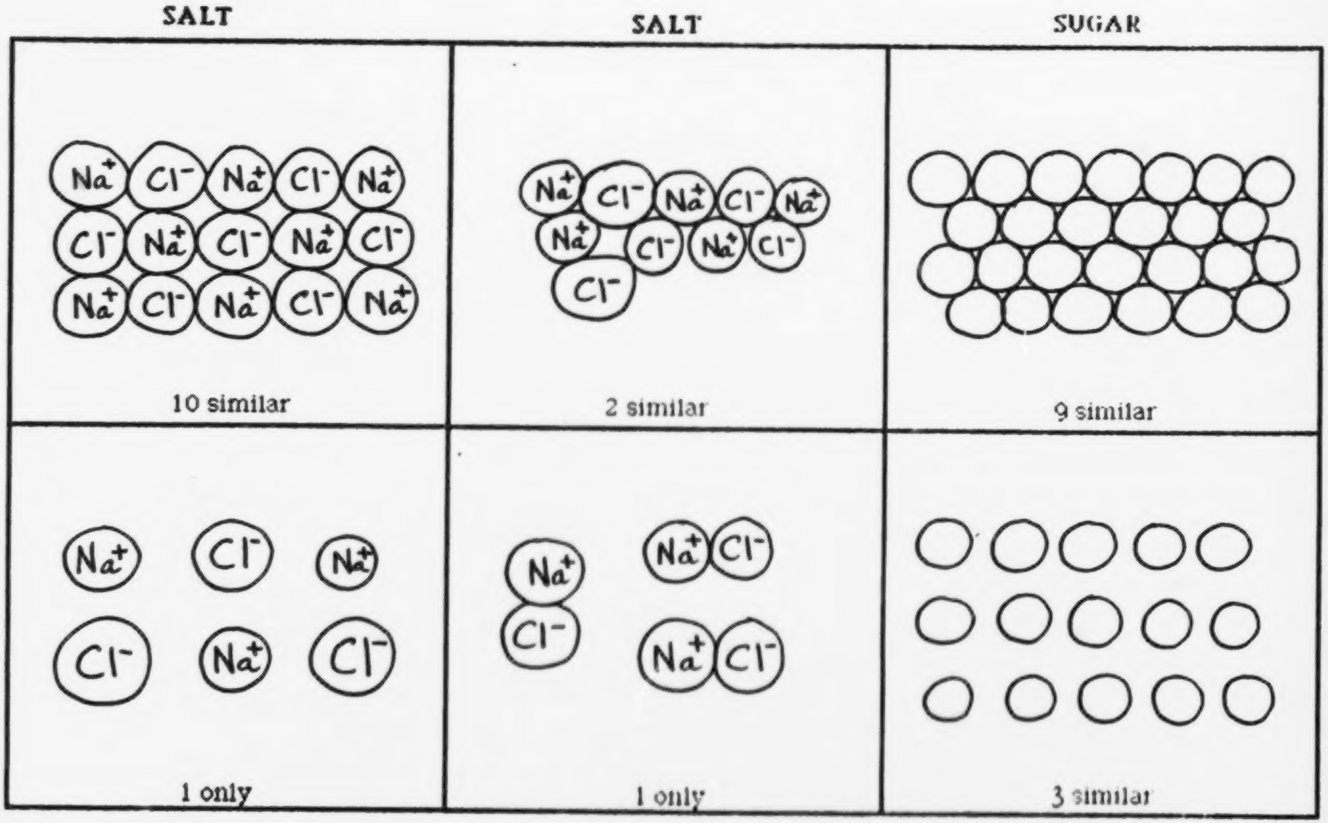
An interview protocol was developed and trialled with two Year 12 students at a high school not included in the survey sample. It was slightly modified as a result of this trial. The final interview schedule began with the student being asked to dissolve salt (sodium chloride) and sugar (sucrose) in water in two different beakers. (Throughout the interview salt and sugar were used as the exemplars of ionic and molecular compounds.) This stimulus was used to promote discussion of the dissolution process. The conductivity of the two solutions was then tested qualitatively using stainless steel electrodes in series with a battery and light globe. The observations were used to promote discussion of the process of electrolytic conduction and the nature of the particles in solution. Students were asked to draw a two dimensional representation of the way they pictured the particles to be arranged in solid sodium chloride and solid sugar and discussion of these diagrams led to an exploration of the student's understanding of interparticle bonds. Two ball-and-stick type models commonly used in NSW high schools were then presented to the student who was asked to interpret each one. These were a model of the ionic lattice structure of sodium chloride and of the infinite covalent network structure of carbon atoms in diamond. There is no model of a sucrose (or glucose) molecule nor a model representing their crystal structure, commonly available in NSW schools, so students were asked to interpret the diamond model again, this time assuming that each black ball represented a sucrose molecule. The relationship between melting point and interparticle bonds was raised to further explore the student's understanding of interparticle forces. Finally the interviewees were asked to predict whether or not a solution of silver nitrate, placed in front of them in a beaker, would conduct an electric current. The solution's conductivity was tested as before and then a solution of sodium chloride was added and an explanation sought for the formation of the resultant silver chloride precipitate.

RESULTS

Because the interview protocol was complex and the interviews had to be carried out by the two researchers each working alone, it was not possible to ensure that all questions and all activities planned for each interview were always carried out. For this reason statistical treatment of the data would be inappropriate. Nevertheless, detailed analysis of 26 of the 28 interviews (one was lost because of technical failure and another aborted because of within school constraints) did provide insights into students' understanding of the concepts involved and pointed to some possible modification of teaching practices and learning resources which might help to clarify some of the misconceptions and confusions revealed. The results will be discussed under the four aspects listed above.

A. THE STRUCTURE OF SOLIDS

Most students associated sodium chloride with ionic bonding and often volunteered information about the nature of the electron transfer process from sodium atom to chlorine atom which results in the formation of this bond. However, this does not imply that they had any clear understanding of the three dimensional nature of the ionic bonding in solid sodium chloride. Molecules of NaCl were often referred to (10 students),


SALT
SALT
SUGAR
Na+ Cl- Na+ Cl- Na+
Cl- Na+ Cl- Na+ Cl-
Na+ Cl- Na+ Cl- Na+
10 similar
Na+ Cl- Na+ Cl- Na+
Na+ Cl- Na+ Cl-
Cl-
2 similar
9 similar
Na+ Cl- Na+
Cl- Na+ Cl-
1 only
Na+ Na+ Cl-
Cl- Na+ Cl-
1 only
3 similar

STUDENTS' DIAGRAMMATIC REPRESENTATIONS OF THE STRUCTURE OF SOLID SALT AND SUGAR

FIGURE 1

sometimes these being said to be held together in the solid by covalent bonds (2 students). Others (2) considered that there was a covalent bond holding sodium and chloride atoms together to form a sodium chloride molecule but that ionic bonds between these molecules produced the crystal structure. Only four students demonstrated a clear and accurate understanding of the notion of a three dimensional lattice of sodium and chloride ions, although more were able to draw two dimensional diagrams which indicated that they did have some understanding of the crystal structure of salt. Some of these representations are shown in Figure 1.

Interpretation of the three dimensional ball-and-stick model of the sodium chloride structure was confused, many interpreting the six wires attached to each ball ("ion") as each representing a bond of some sort ("there is one ionic bond and five physical bonds" and "I would have expected seven wires not six, because chlorine has seven electrons in its outer shell"). Very few (2) were able to explicitly state that the wires did not represent bonds but merely held the wooden balls in place. There were some who believed that sodium ions and chloride ions were released only when the solid dissolved in water ("solid sodium chloride doesn't conduct because it is in separate molecules") and two who believed that an electric current was needed for this dissociation process to occur.

Some students (6) were able to give a clear account of the nature of the bonding between the atoms in a sugar molecule and the nature of the bonding between its molecules in the solid. Terms such as intermolecular and intramolecular forces were used appropriately, as were van der Waal's forces, explained as the consequence of polarity of molecules. But such depth of understanding was uncommon. It was clear that some students had never considered the structure of solid sugar or any other solid molecular compound. Some (3) even considered one sugar grain to be a sugar molecule, relating its structure to that of diamond. It was interesting that the ball-and-stick model of diamond itself was correctly interpreted by almost all students in the sample, even to the extent that it was realized that the network extended in three dimensions throughout a diamond crystal. Some students (2) believed that the particles in sugar were less regularly arranged than those in salt. Many students found the drawing of a two dimensional representation of the arrangement of the particles in solid sucrose an unusual task, although they often accomplished it appropriately. Some of the two dimensional representations of the structure of solid sucrose are also shown in Figure 1.

Nineteen of the 26 students recognized that the bonding in solid sodium chloride was different from that in sucrose, and half this number used the relative bond strengths to explain their statement that salt has a higher melting point than sugar. Only three predicted that salt would have a lower melting point, explaining this in terms of weaker bonds. The link between melting point and interparticle bonds is well understood.

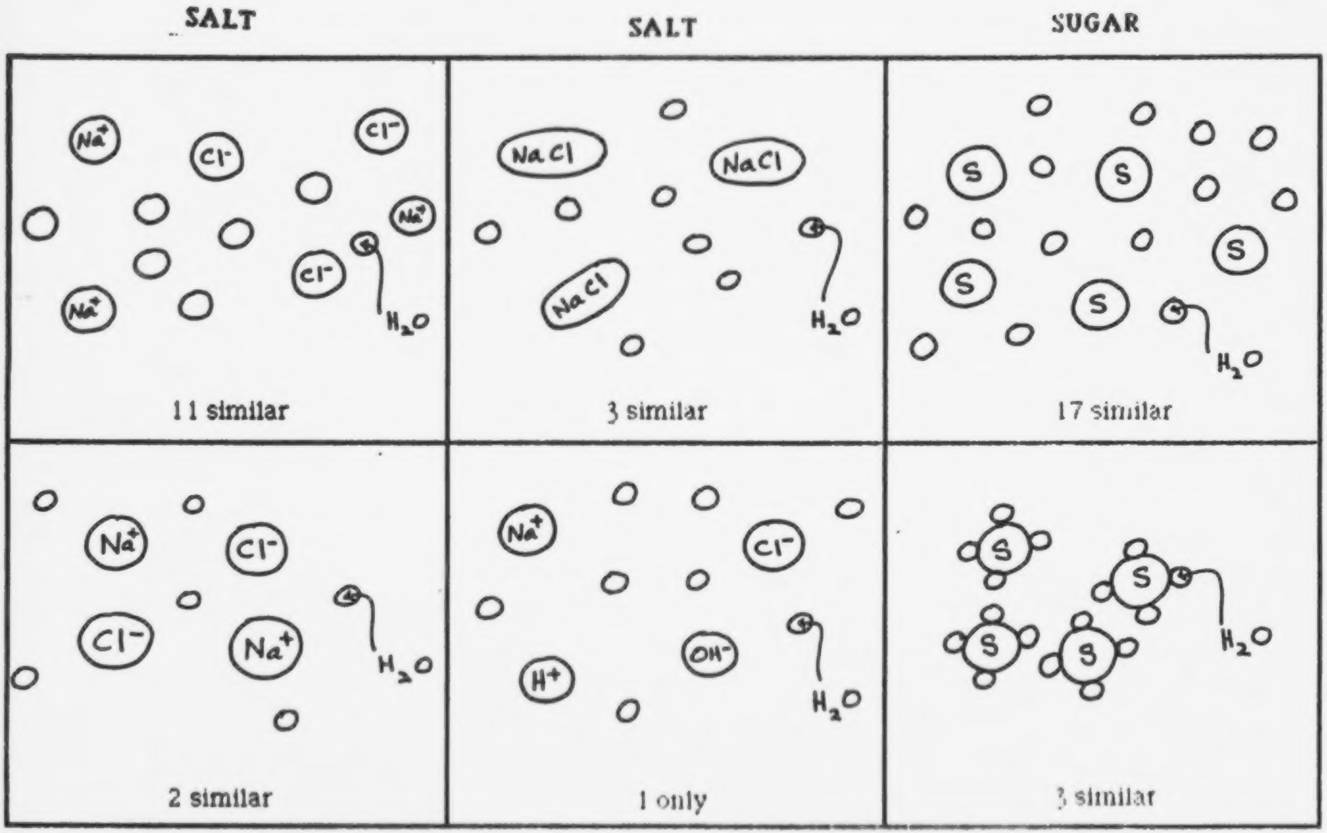
Implications

Students interpret the diamond model correctly but are confused by the ball-and-stick model of sodium chloride commonly used in schools. A space-filling model of salt, with the connecting wires eliminated, might be more appropriate. Furthermore, for consistency, a similar model showing the arrangement of covalent molecules in a molecular solid is urgently required. Teachers could make more use of two dimensional representations of the structure of ionic and molecular solids than they currently do. The old fashioned flannel board has a useful role to play in this regard. It should be realized that students will quite happily refer to ionic bonding in sodium chloride and still think about NaCl molecules, sometimes even invoking covalent bonds to account for the forces between them in the solid. Active comparing and contrasting of the bonding concepts involved seems to be necessary at all times. The following interview extract indicates that even Year 12 students are quite willing to rote learn.

Student:	"The sodium and chloride molecules are ionically bonded"
Interviewer:	"What does that mean."
Student:	(Laughs) "I don't know that!... just know the term".

B. THE NATURE OF THE DISSOLUTION PROCESS

All students except one were able to describe the structure of the water molecule adequately. The one exception claimed that it consisted of H+ and OH- ions. However very few related its polar structure to the process of dissolution, especially in the case of sugar, only three students commenting on the polar nature of sucrose molecules. Four students mentioned the polarity of the water molecule in explaining the dissolving of sodium chloride. All students were aware that the particles in solution would be dispersed thoughout the solution, although it was sometimes stated that there would be some "residual" structure because "the sodium and chloride ions are still there and still attract one another". Two students believed that salt reacted with water to form sodium, chloride, hydrogen and hydroxyl ions. Most students were aware that sugar molecules would be larger than water molecules and that there would be fewer of them in solution. The number of water molecules was usually reported as "millions" to "thousands of millions". A few students (3) reported a definite bond forming between sucrose and water molecules in solution. Almost all students realized that the particles would be ions in the case of salt solution but several were reluctant to use the term "molecule" in referring to the particles in a sugar solution. Figure 2 shows some student drawn two dimensional representations of salt and sugar solutions. It is notable that in all cases the particles in solution are shown to be not touching one another. These diagrams, and other aspects of



SALT

SALT

SUGAR

11 similar

3 similar

17 similar

2 similar

1 only

3 similar

Na+
Cl-
Cl-
Na+
Cl-
Na+
H_2O
NaCl
NaCl
NaCl
H_2O
S
S
S
S
S
H_2O
Na+
Cl-
Cl-
Na+
H_2O
Na+
Cl-
OH-
H+
H_2O
S
S
S
S
H_2O

STUDENTS' DIAGRAMMATIC REPRESENTATIONS OF THE STRUCTURE OF SALT AND SUGAR SOLUTIONS

FIGURE 2

the interviews, indicated that students generally had a better conception of the structure of a solid than they did of the corresponding aqueous solution, especially in the case of sodium chloride.

Implications

The actual process of aqueous dissolution, and the role of the polar water molecule in this process, seems to be poorly understood. Comparing and contrasting the dissolving of salt and sugar, with explicit discussion of the nature and physical behaviour of the particles in the solution formed, supported by appropriate diagrammatic representations or models, might help students to better understand the nature of aqueous solutions of ionic and molecular compounds.

C. HOW AN ELECTROLYTIC SOLUTION CONDUCTS AN ELECTRIC CURRENT

No student in the sample was able to provide a complete and accurate account of this process. All students who made an attempt to explain the conduction of an electric current through a salt solution realized that charged particles were the clue (20 out of 26). However there was often confusion about what these particles were. While none of this group believed that electrons actually flowed through the solution in the way that they flow through a copper wire, the role of the ions in electrolytic conduction was seldom clearly understood. Sometimes the chloride ion (presumably because of its negative charge) was seen as the only ion involved in the process. The idea that "ions just convey the electrons across and complete the circuit" was common. One student used the rather colourful analogy of "ions ferrying the electrons from one electrode to the other". Nevertheless there were 13 students who realized that electrode reactions were involved in the process. In only 6 cases was this statement related to the observation that gases were liberated at the two electrodes. Students who understood this much often became confused when they tried to explain the process in detail and to trace the path of the electrons through the circuit, being unsure of the direction of electron flow. Two students believed that the electrons which constituted the circuit were produced in the beaker; the role of the battery was just to help their flow along.

Implications

The mechanism of electrolytic conduction needs to be explained fully in term of electron flow in the conducting wires, ion migration of both the positive and the negative ions and electron transfer reactions at the each electrode. The sign of the charge associated with each ion and the polarity of each electrode needs to be emphasised, rather than unnecessary use of the terms "cathode" and "anode" which frequently seem to lead to confusion. Again animated diagrams (perhaps computer generated) simulating the process of electrolytic conduction would seem to be a valuable teaching resource.

D. WHY A PRECIPITATE FORMS

Fourteen students predicted that a solution of silver nitrate would conduct an electric current because of the presence of silver and nitrate ions. However another four explained the expected conductivity as due to the presence of silver, a metal and hence a conductor! One student even expressed surprise at the demonstrated conductivity of the solution saying "I generally don't think of silver as a conducting metal". Most realized that the white substance formed when a solution of sodium chloride was added to the solution of silver nitrate was a solid and often it was postulated that it must be either sodium nitrate or silver chloride. Nine of the group who made this postulate deduced that the solid must be silver chloride because "all nitrates are soluble". However very few (2) actually related the formation of the precipiatate to the (low) solubility of silver chloride. Eight students did predict that silver chloride mixed with water would not conduct an electric current because of the absence of ions in solution. Some of these reasoned that silver chloride cannot be an ionic compound since it does not dissolve in water, and so would not conduct an electric current when mixed with water or when melted. Only 3 students predicted that molten silver chloride would conduct an electric current.

Implications

The interview study reinforced the conclusion of the survey study that precipitation from a mixture of ionic compounds in solution is difficult to explain. The belief that all ionic compounds are soluble is not uncommon. Perhaps this misconception is at the root of students' difficulty in explaining why some ions, when mixed in the same aqueous solution, unite to form an insoluble solid. This question needs more investigation than it received in the current study.

AN EVALUATION OF THE CLINICAL INTERVIEW TECHNIQUE

This study confirmed that conducting reliable and valid clinical interviews is not an easy task and that data interpretation is difficult, especially when one is working without full printed transcripts. Factors which appear to have affected the validity and reliability of the interview data include:

1. The tension created by an interview with a strange person;
2. The students' perception that the interview was a test;
3. The interview being out of the context of chemistry, if the student was taken from a class in another subject;
4. The interviewers interrupted the interviewees too frequently;
5. Some planned questions were omitted from interviews due to oversight;
6. The interviews had to be spread over a three week period;

7. The interview is a learning experience for the interviewees and so affects their responses as it proceeds. Thus there were many significant changes of mind on the part of students during the interview. Was this due to the student recalling information overlooked in a previous part of the interview or was understanding being created by the interview process itself?

CONCLUSION

The results of this study suggest that there is no "short-cut" way to obtain valid and reliable data from an interview study. Time needs to be spent in developing the interview schedule which must be trialled not only for its content validity but also to see how interviewees will react emotionally to its approach. The skill of effectively conducting a clincial interview of this type is not easily acquired and needs practice and critical feedback from an informed observer over a period of time in order to be mastered. Research interviews need to be monitored in some way by an external observer to ensure that all aspects of the research questions are covered in every interview. It is unwise to attempt to interpret interview data without having a complete transcript of each interview.

In spite of the limitations of this study, it did reveal several aspects of the topics covered which indicated why students rated the survey items from which the interview schedule was derived as "extremely difficult" or "very difficult". These impliciations can be taken into account by chemistry teachers in the teaching of these topics in the future. Futhermore, the nature of the misconceptions revealed has suggested a series of alternative responses which will be made use of in devising a diagnostic survey instrument for identifying the difficulties which individual students have in understanding the relationship between the structure and properties of ionic and molecular compounds.

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STUDIES IN ASSESSMENT

The Practical Examination Revisited

N.N. Hargraves and P.P. Lynch

INTRODUCTION

The paper describes an experiment in teaching which re-explores the use of the practical examination in biology as a possible assessment/evaluation process. The intention is to generate assessment mechanisms which would support practically-based teaching at HSC level. It should be noted that, initially, there were considerable reservations about such a procedure as a consequence of earlier experiences with such examinations, and these background influences are reviewed in the early part of the paper. The procedures used are then discussed in some detail being derived from Tamir's work in Israel (Tamir, Nussinovitz and Freidler, 1980). The performance data for students using such an approach are provided for the pilot studies conducted in 1984 and 1985. These data did much to stimulate further interest amongst teachers. However, they also pose serious problems for the curriculum developer and subject examiner, and suggest that currently accepted educational rationale in the area many need to be reformulated.

BACKGROUND

Biology teaching at HSC level in Tasmania has, until recently, followed closely to that recommended by the Australian interpretation of BSCS. The use of a text, 'The Web of Life' over a period of 19 years follows a pattern of adoption favoured in other states. However, there has been a growing dissatisfaction with the monolithic influence of the text on teaching style and choice of content which in 1986 resulted in the decision not to compulsorily recommend the text in 1987. The tend ..cy for the text to be used as a source of 'key conclusions' in biology has had a curious straight-jacketing effect on teachers' perceptions of what constitutes biology. These perceptions have become uncomfortably close to being the specific exemplars in text and even to be as limiting as the vocabulary and syntactical structures of the text.

Ironically, a text that was intended to encourage a 'narrative of inquiry' has in fact encouraged the establishment of a 'rhetoric of conclusion'. The reader will no doubt recognise Schwab's (1962) terminology for one of the major dilemmas for the science teacher - How to prevent the domination of 'rhetoric of conclusion'. Some Tasmanian biology teachers' response, apart from attempting to distance themselves from the influence of a single textbook, was to rethink the purpose of practical work. One structure which seemed worth further exploration was the use of a practical examination, and this innovation was stimulated by Pinchas Tamir's account of the Israeli Bagrut examinations which would seem to have had a major influence on the teaching emphasis in that country. (Tamir and Glassman, 1971).

TABLE 2

Preferred Type of Assessment according to Tasmanian Teachers	At Grade 7 and 8 %	At Grade 9 and 10 %	At Grade 11 and 12 %
Continuous assessment (by teachers)	84	78	78
Practical examinations (by teachers)	15	18	12
Practical examination (external)	1	1	0
Both practical examinations (external) and practical examinations (internal)	0	2	10
All above (practical examinations, external, practical examinations, internal and continuous assessment	0	1	0
N =	168	181	55

PREVIOUS EXPERIENCE AND ATTITUDE TO PRACTICAL EXAMINATION

Over the last two decades, Tasmanian science teachers have tended to favour the increasing use of an internal component for assessment purposes. This has been paralleled by a favouring of continuous assessment to complement final examinations. The overall effect has resulted in an internal component with respect to both the theory and practical components of the Biology HSC Courses. Lynch and Ndyetabura (1982) elicited the opinions of science teachers regarding modes of practical assessment and responses are summarised in Table 2.

Teachers offered explanations for their choice of mode, and their reservations and criticisms were associated with questions related to (i) reliability (ii) validity (iii) usability. All three criteria, which are the main criteria on which judgements need to be made, were associated with doubts. Previous experience of university-moderated external practical examinations at HSC level and of university practicals were remembered unfavourably on all accounts in the subject areas of Chemistry and Biology. Teachers expressed reservations about the marking procedures and allocations, the validity/appropriateness of the test questions - what was being tested? They also remembered the operation as being time-consuming, cumbersome and being more of a ritual than an exercises in objective assessment.

The lack of confidence in the exercise was also shared by many of the university staff responsible for the practical examinations. Though, the latter group were more favourably disposed towards the use of such examinations they would admit doubts about the reliability of the marking scheme. The lack of an underlying theoretical basis for the operation seems central to any debate on the issue.

The research evidence available regarding the reliability and validity of current testing procedures for practical work (Tamir et al. 1971, 1980) would suggest that the reservations of the Tasmanian group are well founded. The findings cited have caused those educators most involved in practical assessment at school level to conclude that practical work is a mode of its own and must be treated as such. Implied in this conclusion is the need to re-think the strategies and structures, at present employed, develop new procedures and new instruments for assessment. What is described in this paper is an attempt by a small group to develop new procedures which may be applicable to the State as a whole.

DESCRIPTION OF SAMPLE

Data for the students, teachers and schools in Tasmania involved in the 1984 and 1985 pilot studies are summarized in Table 1.

TABLE 1

Description of Sample: Students, Teachers and Schools involved in 1984 and 1985 Tasmanian studies

Year	Number of Schools	Number of Teachers	Number of Classes	Number of Students
1984	3	9	13	228
1985	2	6	9	165

EXAMINATION FORMAT AND PROCEDURES USED IN THE TASMANIAN PILOT STUDIES

The 1.5 hours examination consisted of three questions which in the 1984 pilot study were adapted from that given to Matriculation Biology students in Israel at the time they took the 'Bagrut' (Grade 12) examinations. Modified forms of similar types of questions were used in 1985 with the same basic format.

The Tasmanian examinations in both 1984 and 1985 were held three weeks before the end of the one year course in Biology A (at HSC level). Biology A is a full, level III subject which in the Tasmanian system means that it counts towards the University entrance requirements of (4 level III and 2 level II subjects).

It was assumed that all classes had completed practical work on topics 'basic' for the course at that level. However, three questions were used to test three skill areas. One of the three questions, dealing with manipulation is given below in Table 3.

TABLE 3

Nature of Question

	The instrument chosen for the test was the microscope. Students were required to prepare their own wet mount (of Elodea), to treat the mount with a solution to make 'before' and 'after' observations, make drawings, and to offer explanations for any changes. Thus there are cognitive skills involved but the manipulative skills and competencies required to use the microscope are the main emphasis of this question, for if these are not achieved explanation and interpretation are not possible.

MARKING THE PRACTICAL EXAMINATION - THE PRACTICAL TESTS ASSESSMENT INVENTORY (PTAI)

The choice of a marking scheme is a criterial issue in the exercise. In 1984, the marking was achieved using a generally recommended format but in 1985 this aspect of the exercise was taken a step further in that an inventory was adopted. The inventory is important in that it defines the area to be tested in terms of the major criteria to be addressed, as well as providing a quantitative scaling for responses to these criteria. The PTAI inventory as reported by Tamir, Nussinovitz and Friedler (1982) was used in view of the fact that the reliability, validity and usability of the inventory had already been established.

MODEL MARKING SCHEMA: AS USED FOR ISRAELIE STUDENTS

The full details of these procedures are provided elsewhere (Tamir, Nussinovitz and Friedler, 1980) including representative answers of students. What emerges, using this approach, is an assessment and marking scheme which is unambiguous, objective with respect to rankings, and easily quantifiable when final marks are to be determined.

In Tasmania, remarking of random samples of scripts was undertaken and revealed minimal variations in the initial marks allocated by different teachers to the student's answers.

The use of an inventory like PTAI was not found to be unwieldy and overly time-consuming in practice, and teacher confidence in the reliability and validity of the marking process was considerably enhanced after the experience of using the inventory.

INSIGHTS PROVIDED BY STUDENT PERFORMANCE IN RESPECT TO RELIABILITY AND VALIDITY

Perhaps the greatest resitance to the establishment of new assessment procedures for practical work is due to strongly felt doubts about the reliability and validity of the procedures. Few teachers would use the terms 'reliability' and 'validity' in a way that would fully suit the specialist in educational measurement but the confidence that teachers have in standard theory examinations does not usually extend to the assessment of practical work. In many cases, and Tasmania would fall into this category, there is a residual prejudice towards the practical examination based on previous unfavourable experiences. This lack of confidence in procedures also extends to university work where the marking of a 'laboratory report' still remains the most usual method of assessment in spite of its many unsatisfactory aspects, not least the problem of mindless copying.

However, the student performance data provided by the pilot studies in 1984 and 1985 does throw some light on these issues. The theory underlying the test construction can be validated to some extent by examining mark distributions and correlations. Reliability can be checked in a similar way and scripts subjected to remarking by the same and different markers.

TASMANIAN STUDENT PERFORMANCE DATA: THE MARK DISTRIBUTION FOR EACH TEST ITEM

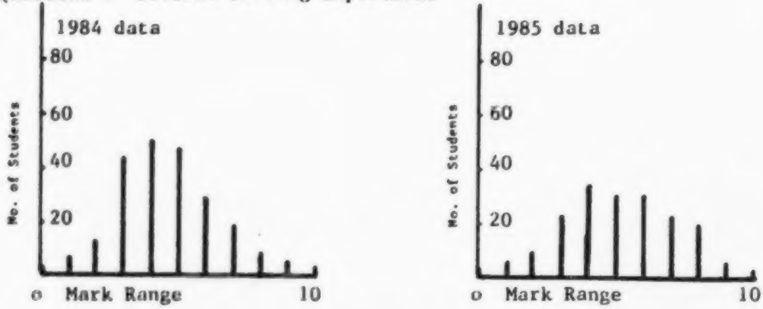
The three questions used in the practical examination were classified broadly as:

Problem Solving	Q1.
Classification	Q2.
Manipulative skills	Q3.

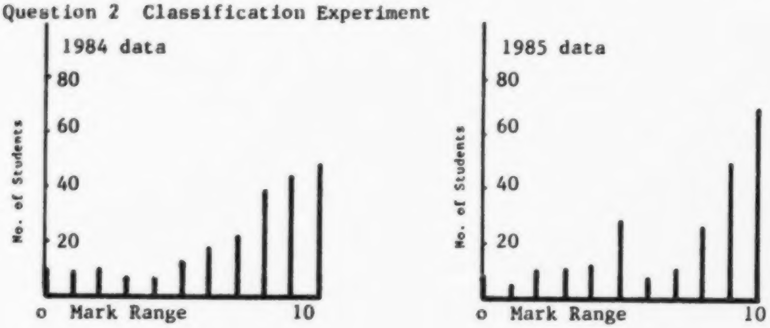
The mark distributions are provided in Fig 1 for 1984 or 1985.

FIGURE 1

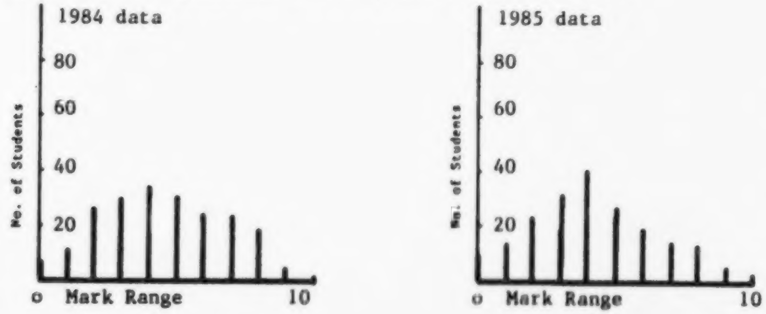
Tasmanian Student Performance Data:
Mark Range and Distribution for Test Scores



Question 1 Problem Solving Experiment



Question 2 Classification Experiment



Question 3 Manipulation Skills (Microscopy) Experiment

Explanation for the change in mean mark can be made in terms of degree of difficulty (c.f. Q3 for 1984 and 1985) but what is most striking is the form of the distribution for the classification question which for a substantial proportion of students represents a mastery test, successfully completed.

Whereas in 1984 and 1985 there were only 3 and 2 schools respectively, in the years samples, a further practical examination was conducted at the end of 1986 which involved 22 schools. Although the more detailed findings of this third pilot study are not included in this paper it would seem appropriate to comment on the differences observed between schools.

It would seem that schools are 'doing differently' in that there are some schools with mean scores that are significantly higher than average and some where the scores are significantly lower - for any of the three questions. Explanations for these differences are of considerable professional interest and will be reported at a later date but at this stage we wish to emphasise the fact that there is a large variation between school performance.

TASMANIAN STUDENT PERFORMANCE DATA: CORRELATION BETWEEN QUESTIONS AND IMPLICATIONS FOR VALIDITY

The three categories problem: solving/classification/manipulative skills (as determined by Q1, Q2 and Q3 respectively) represent three different outcomes of practical work. Implicit in the latter statement is the notion that the three domains are different and need to be assessed differently. The student scores were cross-correlated Q1 vs Q2, Q1 vs Q3 and Q2 vs Q3. A summary of the correlation co-efficients are provided in Table 5 for the 1985 examinations.

TABLE 5

Correlation Coefficient of Performance (Marks) between Practical Test Items

	Correlation Co-efficient
Q1 vs. Q2	0.07
Q1 vs. Q3	0.17
Q2 vs. Q3	0.04

The lack of correlation between questions observed in Table 5 is immediately striking and we would offer this as strong evidence for the autonomy of the underlying test constructs-that they are not one and the same thing. Whether correlations are improved as teaching emphases change remains to be seen but we were surprised ourselves at the extent of the lack of correlation.

TASMANIAN STUDENT PERFORMANCE DATA: CORRELATION BETWEEN PRACTICAL MARKS AND HSC (theory mark)

The HSC theory paper is designed to test the 'analytic' and 'constructive' modes of performance in biology (Tamir's terms). To what extent are overall theory marks correlated with the 'practical' mode as measured by data obtained from Q1, Q2 and Q3? The correlation co-efficients are provided in Table 6.

TABLE 6
Correlation Coefficients of Performance (Marks) between
Practical Test Items and HSC Theory Mark

	Correlation Coefficient
Q1 vs. Theory	0.29
Q2 vs. Theory	0.22
Q3 vs. Theory	0.43

It appears from Table 6 that performance in the practical mode is largely unrelated to that obtained from the 'analytic' and 'constructive' modes which adds further weight to the practical mode being a distinct identifiable and measurable state of performance in biology. Howevery, it also raises issues as to how the marks obtained should actually be used.

CONCLUSION

The pilot studies, and that includes the more recent 1986 study which involved 22 schools, have done much to convince teachers and educators in this State that the 'practical' mode in biology can be assessed satisfactorily using the processes described.

The performance data, the teachers responses and the test/re-test procedures tend to confirm the reliability, validity and usability of the practical examination, in spite of inital doubts by many teachers in that regard. How the results of the practical examination are used remains to be decided. They could be used alone or in conjunction with marks obtained from continuous assessment of practical work done over the year. They could be used directly or as a moderating instrument only. In view of the recent decision by the subject committee to allocate a considerable percentage of the overall mark to practical work, specifically (25%), it seems highly likely that the results may well be used directly. The strategies employed in this study may well be appropriate to physics, chemistry and geology, though the choice of criteria to be tested, the form of the Practical Test Assessment Inventory and the marking scheme may need to be substantially modified for those particluar subjects.

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AN ANALYSIS OF TEACHERS' AND THEIR STUDENTS' VIEWS OF THE CONCEPT "GRAVITY"

Catherine Ameh

INTRODUCTION

Teachers have been reported to have misconceptions in science (see Ameh and Gunstone, 1985, 1986) but there is no direct report which considers whether teachers' misconceptions are similar to those of the students they teach. Research in this area has very largely been focused on students. This is rather unfortunate because the teacher plays the crucial role in any educational enterprise. Teachers' understanding of science should be a paramount interest to researchers. Hewson (1981) has argued that while the research focus has been on students, teachers might have misconceptions which will require changing.

According to Northfield (1986), current views of science education see the science teacher (not curriculum materials) as the primary focus for curriculum development. Efforts have been made to change students' views towards more scientific conceptions (e.g. Champagne et al., 1983; Osborne and Wittrock, 1983; Gunstone and Northfield, 1986). In most of these attempts the science teacher is not considered. Tisher (1986) has argued that educating primary and secondary school teacher is a major enterprise, yet teachers appear to receive only a small amount of attention from researchers.

In this paper, we analyse the differences and similarities between teachers' responses and their students' responses to questions probing understanding of "Gravity". The aim is to establish whether or not students' responses reflect the beliefs of their teachers, and to consider whether teachers' concepts are superior to students' concepts.

Sample

This is only one aspect of a larger study undertaken in Nigeria. For the research reported in this paper, four teachers involved in the larger study have been selected. Teachers in the larger study were volunteers who agreed to take a concept test. The subset of teachers considered here were also asked to nominate any ten of their Form 3-5 students who studied physics, chemistry and biology. These students then provided the data discussed below.

METHOD

Science teachers were given a pencil and paper test based on the work of the New Zealand Learning in Science Projects. The test probed eight concepts of which "Gravity" (being considered here) is one. Three gravity situations were presented: picture of a man standing on the moon, standing on earth and falling from a plane. Respondents were asked about the magnitude of gravity in relation to the earth. Options were provided. Teachers were later interviewed about their written responses. Their students were also interviewed. The interview for both teachers and students took the same form: the Interview-About-Instance technique (Osborne and Gilbert, 1979). The selection of responses reported below are coded "T" for teachers and "S" for students. In addition, the number of years' teaching experience is given as a subscript (i.e. T_1 indicating teacher with one year of experience). For students, subscripts show their teacher, their form, and a serial number (i.e. S_{1-401} indicates student taught by teacher T_1, in form 4, serial number ol). "I" is the interviewer.

FINDINGS

These are presented by teacher.

Teacher A:

The question "Is there gravity on the moon?" produced the following responses.

T_1 "Yes but much less than on the ground. We have gravity everywhere."

S_{1-401} "Yes but much more than on the earth because as you go up, the gravitational pull increases."

I: "Where is the gravity pulling from?"

S_{1-401} "From the air around us - our surroundings."

I: "What is gravity?"

S_{1-401} "It is the pull of the earth on objects - force attracted by the air."

S_{1-402} "No gravity on the moon, unless he is wearing the Appollo thing that they wear to go to the moon. If he is wearing them, at least I will say that there is gravity. If not wearing anything, no gravity. There is no gravity on the moon, aeronauts will not be wearing space suit".

S_1-403 "No gravity because you weight less on the moon".

S_1-404 "No gravity becasue the higher you go the less you weight. Only us on earth that have force of gravity. Now that he is no longer on earth, but on the moon."

I: "What is gravity?"

S_1-404 "Gravity is a type of force that pulls one down or an object down to get the actual weight or mass"

S_1-405 "No there is no gravity."

S_1-406 "No because he is far away from the earth. If he was on the earth, the gravity here is less, if he jumps, he is surely to come down but if he is on the moon, he can float on, so he won't come down."

I: "Is there gravity when standing on earth?".

This teacher and all his students said "Yes".

I: "Is there gravity on a person falling from the plane?".

T_1 "No there is no gravity because the higher you go the less the frictional force on you. If a man is on the air, although there is a tendency for him to come down because the pressure there is less due to the reduced air in the atmosphere, reduction in the gravitation pull as you go higher."

S_1-401 "There is no gravity because he is going downwards. There is gravity only when something is going upwards."

S_1-402 "Yes there is gravity since he is falling from the plane, the pull of earth pulling him down. If there were no gravity he will just keep on staying there, flying in the air."

S_1-403 "Yes there is gravity but much more than on the ground because the pressure or the force that he is using to come down is great and if he is ... the pressure will be increased."

S_1-404 "Yes but much less than on the ground because the person is still on earth and as I said before, the higher you go the less you weight."

S_1-405 "Yes, about the same as on the ground, he is still on earth".

Teacher B:

For the question: "Is there gravity on the moon?":

T_8 "Yes but much less than on the earth."

S_8-313 "No gravity because a person can not stand on the moon because I thought a moon is a spirit - like air."

S_{8-314} "No because there is no force of gravity in the moon, no weight in the moon, but there is weight on earth."

I: "What is gravity?"

S_{8-314} "A force pulling one to the earth."

S_{8-315} "Yes there is gravity on the moon but much less than on earth because before he moves, he moves very slowly, his movement is not as fast as that of someone standing on the ground."

S_{8-316} "Yes same as on the earth because if he jumps up, the force on the earth will draw him down.:

S_{8-317} "Yes but less than on the earth because there is no air there but there is plenty of air here."

S_{8-318} "No because he is standing on the moon and there is nothing like weight there."

S_{8-319} "No gravity. On earth if you stand there is gravity, but if you have passed the earth, there is no gravity."

For the person falling from a plane:

T_8 "Yes but much less than on the ground because as we move away from the ground, the distance is increased, so the gravity is going to be less. Increase in distance, less force that will act on that body."

S_{8-313} "No, because as if he has gravity he will not fall out of the aeroplane."

S_{8-314} "Yes but the wind will try to oppose the gravity so the gravity will be less."

S_{8-315} "Yes much less than on the ground because he is not yet having a friction on the ground, because there is no friction between him and the ground."

S_{8-316} "Yes much less than on the ground because the ground is further than where he is jumping down from the plane."

S_{8-317} "Yes less because he is coming from up."

S_{8-318} "Yes because air will help him to come down very fast, much more than on the ground because he is ..."

S_{8-319} "Yes much more because he is falling down to the ground."

Teacher C

For a man standing on the moon:

T_5 "Gravity is less due to the shape of the earth. Gravity is a force which tends to attract all bodies to the centre of the earth and due to the shape of the earth, the gravity varies from one particular point to the other. Gravity will be greater at the poles than at the centre."

S_{5-420} "No there is no gravity on the moon because on the moon, a person can lift 600 kg but if it's on the earth, he cannot lift it up because there is force of gravity."

S_{5-421} "No because on the moon, if he jumps, nothing will bring him down so he will try to come down on his own."

S_{5-422} "No gravity because if there was gravity like that of the earth, and the moon is spherical the man will fall down and he won't have been able to stand."

S_{5-423} "No gravity because he is standing on the moon, not that he is free on his own that if he is up he will still just come back to the same thing."

For a person standing on earth, all except one student said "Yes there is gravity." The exception stated:

S_{5-423} "No, he is standing on his own, he is not up."

For a person falling from a plane:

T_5 "Yes much more than on the ground because his weight or his own gravity is all over the earth, so if the person is very close to the ground, the force is not much, he will just come down easily. Even if he falls on the street, he will have no fracture but if it is from the plane he will have a fracture because the force of gravity there is more."

S_{5-421} "Yes much less than on the ground because he won't be coming as fast as he would if he were much nearer the ground."

S_{5-422} "No because he is neither on the ground nor in the space, he is just in the air."

S_{5-423} "Yes more than on the ground because he is falling straight so the gravity is quite quicker."

Teacher D:

For the instance of person standing on the moon:

T_{14} "Yes but much less than on the earth because the moon is one-sixth of earth's gravity. The moon has its own gravitational field but the earth is larger than that of the moon."

S_{14-507} "Yes there is gravity."

S_{14-508} "Much less than on the earth because when he is on the moon, the gravity that acts on the moon is very little."

I: "What is gravity?"

S_{14-504} "Gravity is the process whereby the earth or the surface of the earth or moon act on each other."

S_{14-509} "Yes but much less than on the earth because the gravity in the moon is less than that of the earth surface because the centripetal force keeping the gravity is much."

I: "What is gravity?"

S_{14-509} "Gravity is the attraction between two bodies."

S_{14-510} "No gravity on the moon."

S_{14-511} "Yes but much less than on the earth because its natural, the earth is the most one, because on earth all of us are standing on the ground because of the gravitational pull but in the moon people will be floating around and around because it does not have much gravity."

S_{14-512} "Yes but much less than on the earth because the higher you go, the lighter it is because the gravity will become less."

When asked: "Is there gravity when standing on earth?"

T_{14} "Yes."

S_{14-512} "No gravity on the man on earth. The gravity is only acting between the earth and the planet. There is no gravity on human, but there is a force that is pulling him to the surface of the earth.

Falling from a plane:

T_{14} "Same as on the ground because the-man is within the earth's gravitational field."

S_{14-507} "Yes less than on the ground because he is in space far ahead. The gravity has some relationship between the distance above the ground so the distance will have some effect."

S_{14-508} "Yes because of the gravity that is acting on him that he is falling down. The gravity will be much less than on the ground because when the man falls down he is not going under the ground but on the surface of the earth."

S_{14-509} "Yes the same as on the ground because it is in the atmosphere."

S_{14-510} "Yes less because the pressure, the higher you go the more the pressure becomes so the pressure at the upper part of the earth i.e. the gravity at the upper part of the earth is much less than gravity at the lower part of the earth."

S_{14-511} "Yes much more than on the ground, the gravity is pulling him down that is why he is falling."

S_{14-512} "Yes but much more than on the ground because as he is falling, the gravity on his body increases - the force acting on his body will be less because he is losing it."

DISCUSSION

The teaching responses which seem to clearly show misconception are, for falling from the plane: T_1, T_8, T_5 and for gravity on the moon: T_5. In each of these cases the specific teacher misconception is not common (or often even present) in the students. This small sample suggests that teacher misconceptions may not be passed to their students.

This is not surprising, as teachers with misconceptions are more likely than teachers with substantial understanding to rely heavily on student texts. That is, teacher with misconceptions are more likely to rely on authorities other than themselves. Hence they are less likely to teach their own conceptions than a teacher with understanding.

There is a variation in responses between the students. The students' concept of gravity is characterized by the form the student is in. Form Three students demonstrated a very naive conception of gravity. [illegible] them associated gravity with air and pressure. Form Four and Five students did not have a scientific concept of gravity, but they tended to use better language to express their misconceptions. Osborne and Freyberg (1985) also noted that older students in their samples included more sophisticated or technical words in their descriptions but their views appeared to remain essentially those of much younger children. In considering the three forms put together, the Form Five students' responses for standing on the moon are more acceptable. Most of them accepted that gravity is a force that acts between two bodies. Some common beliefs among all Forms, 3-5, are: gravity is something that emanates from the centre of the earth; the further away the body the more the pull; when something is coming towards the earth there is no gravity, only when something is moving away from the earth that there is gravity. Based on the belief that there is no gravity when coming towards earth, a student claimed that there is no gravity when standing on the earth. The example of a person being able to lift 600 kg on the moon but not on earth, was used as a basis to justify the absence of gravity on the moon.

Teachers and students' responses in this report have clearly indicated that students are not using the knowledge taught to them in science by teachers, neither are the teachers using scientific knowledge to answer science concept questions. How do science educators reconcile such issues of teachers' teaching not influencing students' understanding, or even the superficial learning of science teachers? This report particularly calls the attention of researchers to the discrepancies that exist between teachers' and students' learning.

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ASPECTS OF THE NON-FORMAL PROMOTION OF SCIENCE EDUCATION IN THE EASTERN CAPE, SOUTH AFRICA

Paul Webb

INTRODUCTION

In South Africa, as in other developing and developed countries, science is generally recognised as a critical subject in a rapidly changing technological world and was pinpointed as an area requiring special attention by the de Lange commission on education (1981). Nevertheless pupils are exposed to underqualified and unqualified science teachers in all South African education departments.

The Department of Education and Training's 1979 annual report revealed that of the teachers in black secondary schools 25% had a qualification of standard eight or lower, 58% had standard ten, 8% had incomplete university degrees and 9% were graduates. This lack of training is part of a set of circumstances which undermines teachers' confidence and encourages self-defence by means of a teacher-centred approach and an autocratic classroom environment. The result is a system where the number of failures at DET schools increased from 24% in 1978 to 52% in 1983. Science is a major failure area and therefore is not taken by the majority of pupils. Those that do select science as a subject are often subjected to underqualified teachers who do not have a solid scientific background and who have not been immersed in the philosphy of science and who therefore cannot be expected to exhibit enthusiasm for the subject, let alone make it interesting and meaningful for their pupils.

SENIOR SCIENCE

Science in-service training workshops for senior school teachers held at the Centre for Continuing Education were initially aimed at delegates from Port Elizabeth and the surrounding districts, but activities have subsequently expanded to include other circuits and have drawn participants from as far afield as Mossel Bay, Colesburg, Queenstown, East London and Cape Town.

The main aims of these workshops are to:

- increase syllabus content knowledge and enrich the general scientific knowledge of teachers.
- develop and improve scientific and teaching skills.
- develop teacher self-confidence and self-sufficiency.
- foster enthusiasm for science and science teaching.

Workshops run for 2 to 5 days, depending on content to be covered and course leaders, are drawn from CENCE and the Physics, Chemistry, Computer Science, Zoology and Education Departments of the University of Port Elizabeth. Experienced and talented science teachers from Port Elizabeth schools and visitors from Rhodes University are also utilised. These course leaders are chosen carefully for both their academic expertise and their ability to relate to people in an informal learning environment.

Teachers are involved in the planning of their courses and put forward opinions and suggestions as to the content of future work. These, together with observations made by course leaders in workshops and suggestions from departmental subject advisors, assist in the determination of entry level and the formulation of attainable goals.

Course content has included Chemistry, Physics, Electronics, Computer literacy, Biology and Ecology as well as management skills for Heads of Science Departments and methodological practice through micro-teaching. Teachers attending courses are usually grouped as to the standards they teach, and on ocassion as to position held, e.g. Heads of Science Departments.

Self activity is encouraged and lecturing is kept to a minimum. One method used is to provide teachers with scientific apparatus pertinent to schools and to allow them to work through a practical session after which they reconvene as a group and discuss the theoretical background and most effective classroom methodology. Teachers also make simple apparatus and exhibits from materials provided by the Centre which they then take back to their school for classroom use.

Methodological skills for more effective science teaching are promoted by micro-teaching sessions in which lessons are video recorded, discussed and evaluated by the group. Emphasis is on confidence building by shared experiences, teaching before peers, seeing other teach, exposure to different teaching methods and working with apparatus.

Workshops start with basics and vast subject knowledge is not presupposed, but working on the premise that teachers have a need and desire for deeper understanding of their subject in order to present it more meaningfully, enrichment components are included. An example of this is a workshop aimed at enriching teachers' background and understanding of ecology by taking them through ecosystem analysis in the field. It is understood that working within the constraints of the schools system few teachers will be able to repeate the exercise with their pupils but nevertheless such experience should enrich the teachers' understanding and teaching of ecology as it is a topic where facts alone are inadequate and there is a real need for practical and field experience.

All workshops are intended to be enjoyable experiences where teachers have the opportunity to discuss problems with those outside and within the teaching profession.

PRIMARY SCIENCE

The Centre for Continuing Education promotes science education in Junior Schools by means of short courses and by "care-kit" training. The Urban Foundation "care-kit", designed by irrepressible glob-trotting granny extraordinaire, Mrs. M.A. Griffiths, is based on a less comprehensive unit used by the Natal Education Department and ideas from Japan, Singapore, the Californian "Science on the shoestring" project and UNESCO guidelines for science education.

Practical apparatus for ten groups of pupils per class for all the experiments requirements by the standard 3, 4 and 5 syllabi as well as equipment for teacher demonstrations is provided for in the kit. To conduct experiments the teachers need only supply water - everything else has been provided, even matches.

Cost effectiveness is achieved as many of the kit items are manufactured from waste materials, e.g. spring balances made from old plastic syringes collected from hospitals and spirit burners constructed from used purity bottles. Japanese inspired mulipurpose interlocking apparatus reduces the number of articles required to demonstrate a whole range of scientific principles e.g. a rectangular wooden block with sandpaper on one side, holes drilled to accommodate test tubes, a hook at one end and which has the mass of 102 grams can be used:

- as a test tube stand
- as the base for a balance
- for calculating and teaching the concepts of area, volume and friction
- to allow the pupil to experience a force of 1 newton produced by gravity

The kit is produced by the Cripple Care Rehabilitation Centre for the Physically Disabled, hence the name CARE KIT. This centre provides training and preparation opportunities for the placement of the disabled in nonsheltered employment. Production of the kit has introduced new and varied tasks for participants such as welding, turning and the handling of a stamping press to cut out callipers from sheet metal.

The Urban Foundation sponsors one kit per school but before a school can acquire the apparatus their standard 3, 4 and 5 teachers must attend a week long training session in the use of the materials and methodology. Teachers who attended training courses at the Centre for Continuing Education have been tutored by competent and enthusiastic teachers from local primary schools, visitors from Training Colleges and Universities and interested engineers.

Evaluation of the training course was made by means of a questionnaire and the teachers responses were positive and enthusiastic. An indicator of the need for such training is that of the 48 in-service science teachers trained, not one had handled a thermometer in class, even though the syllabus requires them to do so.

Experiences such as laboratory work and demonstrations help pupils restructure their existing non-scientific conceptions of natural phenomena and allow meaningful construction of knowledge and understanding of science, a key subject in an age of technology. As technical diploma's and degrees cannot be obtained without a knowledge of Physcial Science the junior school science teacher lays the foundation for possible employment in a field which offers many opportunities.

PUPIL PROGRAMMES

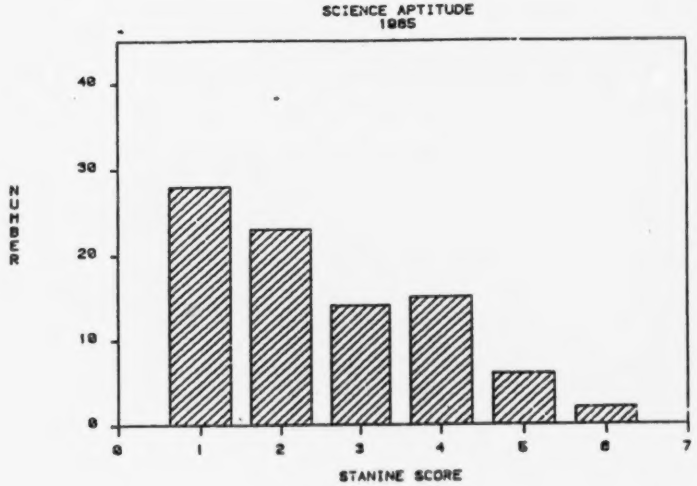
Pupil programmes offered by the Centre concentrate on the key subjects identified by the de Lange Commission i.e. Physical Science, Mathematics and English. Programmes are offered in two forms:

a) Pupil enrichment after school hours
b) Full matriculation classes.

Both programmes are aimed at able pupils with high aspirations who are disadvantaged because of their social condition. The disadvantaged nature of the pupils concerned, although selected as the best in the Port Elizabeth black school population, is reflected in the results of aptitude tests which rated 74% as weak.

FIGURE 1

Bar graph of stanine scores achieved by pupils in science aptitude test.



When interpretating aptitude test data (Fig. 1) it should be remembered that individuals cultural background as well as their informal training and the richness of experiences encountered in the course are of crucial importance to aptitude test performance, and to success in formal learning situations (Goslin, 1986).

The aptitude tests given are not standardised for blacks and therfore were evaluated with caution, but it must also be remembered that the type of education that these pupils receive, and the examinations for which they sit, are also not standardised for blacks. The aptitude tests thus do provide insight to the pupil's frame of reference. Dyer (in Goslin, 1966) points out that it is not the aptitude tests which are unfair to culturally deprived groups, but rather the hard fact of social circumstances.

OBJECTIVES

Programme objectives may be expressed as long or short term. The short term objective is that pupils should pass the matriculation examinations and, because of improved language ability, perform better in all subjects taken. The long term objective is the prepartation of individuals for competent performance at tertiary institutions by developing study skills.

After Hours Enrichment Programme - Selection and Evaluation

Pupils from all Black high schools in Port Elizabeth were selected to attend a two year enrichment programme on the strength of their acheivement in the Junior Certificate examination and the results of standardised H.S.R.C. aptitude tests. Selection procedure allows the most promising 30 (teacher selected) pupil applicants from each school to undergo IQ and aptitude tests. From each group 15 pupils were selected to be part of the programme while the other 15 provided a control group against which progress could be measured.

Pupils evaluated the programme by questionnaire and were themselves evaluated. Analysis was made of differences between participants and the control group in different schools and of differences between schools.

Table 1 indicates how pupil achievement within schools changed over six months. A plus sign indicates a percentage increase on marks attained in the Junior Certificate examination and a negative sign indicates a percentage decrease. A dash (-) indicates that results in that subject were not provided by the schools.

TABLE 1

Analysis of change in pupils marks over six months

		PERCENTAGE CHANGE		
SCHOOL	SUBJECT	UPP PUPILS	CONTROL GROUP	DIFFERENCE BETWEEN GROUPS
KWAZAKELE	English	+ 5	-17	22
	Mathematics	-	-	-
	Science	+ 9	- 5	14
TAMSANQA	English	+ 4	+ 1	3
	Mathematics	- 3	- 1	- 2
	Science	+17	- 1	18
ITEMBELIHLE	English	- 3	- 9	6
	Mathematics	+12	- 9	21
	Science	+17	- 4	21
NEWELL	English	-	-	-
	Mathematics	-31	-17	-14
	Science	- 3	-19	16
LOYISO	English	+ 2	-10	12
	Mathematics	+ 5	- 2	7
	Science	-10	-13	3
KWESI LOMSO	English	+ 3	+ 3	0
	Mathematics	- 7	-24	17
	Science	+18	- 3	21

Improved mark status by pupils attending the programme as compared to the control group was:

English	4%	$p > 0.05$
Mathematics	10%	$p < 0.05$
Physical Science	17%	$p < 0.01$

FORMAL MATRICULATION PROGRAMME

Formal classes were intiated at the request of pupils who have had their education disrupted by boycotts and violence in the townships. Seven subjects are offered and pupils are required to take Physical Science, Biology and Mathematics. More students apply to attend the programme than can be accommodated and classes are taught by highly selected teachers and university personell, which has resulted in a number of university placements in scientific direction.

CONCLUDING COMMENT

2.8% of the Black population of 18 years or older in the Eastern Cape area have a standard 10 qualification as opposed to 40.5% of the White population (Erwee and Radder, 1984). This small percentage, plus the fact that Erwee and Radder (1984) record only 200 Black graduates in the metropolitan area (population 365,000), underscores the need for pupil support and black education in South Africa in general and science education in particular, as well as emphasising the need for involvement by non-formal educational agencies such as the Centre for Continuing Education which runs programmes funded by the private sector.

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PARENTAL INVOLVEMENT IN A SCIENCE PROGRAM

David Symington and Dorothy Hayes

INTRODUCTION

Although there has been ever increasing participation of parents in the formal teaching/learning process in schools, the report to be presented here is significant in several ways. For one thing, it reports the involvement of parents in a rather a typical role. First, most frequently parents are involved with pupils in a withdrawl situation. In this case each parent handled a group of children where the whole class, divided into groups, was operating in the classroom.

Second, whereas most frequently the parents are involved in activities in language and/or mathematics, in this instance the activities were part of the science program.

Third, parental participation often begins from a deficit model where parents are asked to help individual children overcome their problems. The program, by contrast, was based on the desire to create and appropriate learning experience for all children and this needed parental support.

The second significant feature of the report is that it involves an evaluation of the participation of parents. Usually all of the available resources are directed to mounting a program and evaluation is not seen as a priority. In this case the school welcomed an evaluation of the program.

The Classroom Program

The program evaluated involved parents in series of 6 cooking activities taken as part of the course in science for the infant grades on the topic of Change. The children involved were in grades 1 and 2. Each class had a one hour session per week taken by the one teacher.

Parents were informed about the program and invited to assist. Those who volunteered were scheduled to help with one or two lessons with the class of which their child was a member. The teacher distributed to the parents, some days before the session, a sheet which would help them to prepare for their involvement.

Each session began with an introduction by the teacher. The children were then divided into four groups. The teacher normally took one group and each of the three parents managed one of the other groups for the cooking and cleaning up. After the cleaning up the children came together to complete a worksheet and to participate in a discussion.

The Direction of the Evaluation

The responsibility for the direction and nature of the evaluation rests entirely with the evaluator. The focus of the evaluation was not simply on the learning of the pupils. In belief that the impact of participation may be as important for the parents as for the children, it was decided to gather data related to changes in the pupils, the parents and the program itself.

The classroom teacher and principal were shown the research questions and the suggested methodology. On the basis of their approval the evaluator approached participating parents with a view to them volunteering to be interviewed two weeks after the first lesson in which they were involved.

Methodology for the Evaluation

A structured interview format directed the interview of the parents. The interviews were recorded on audio-tape. In all, 21 of the 36 parents volunteered to be interviewed. The teacher was interviewed, again following a format suggested by the research questions. This interview was also audio-recorded.

To gather data from the children, all of the children in one class were asked by the teacher, several weeks after the lessons concluded, to do a drawing of the cooking activity. The following week the evaluator interviewed the children in this grade. The interview began with a discussion of the drawing but then moved on to cover issues related to the parental participation in the science lessons.

ANALYSES OF THE DATA

Question 1

What do the parents see as the value of their participation in this program?

There was considerable diversity in the ideas expressed by the parents about the value of their participation.

1. Most parents indicated a belief that it was of value to the children. Some said that the child's attitude would be improved by their involvement. One parent reported that when, due to pressure of other commitments, she withdrew from participating in

the school life her son became aggressive. This undesirable behaviour ceased when she resumed her former involvement.

Others saw their involvement in terms of the benefit to all children. They suggested that the children gain from the opportunity to interact with another adult.

Some talked specifically about the cooking activity indicating that although they involved their children in cooking at home not all parents did. Accordingly, they saw themselves as contributing positively to the development of other people's children.

2. There were parents who spoke of the gains for those adults who became involved. Some indicated that they had learned a good deal about their child's relationship with her/his peers. Others spoke of the benefits to themselves in terms of understanding the class dynamics or of knowing more about the school program.

3. One parent suggested that parental participation was valuable because better informed parents would, by their influence, keep the teachers operating at an optimal level. This parent talked of 'shaking up the system'.

Surprisingly, no-one suggested that their contribution might be a form of encouraging the teacher. Perhaps this was due to their perception of the teacher as competent and enthusiastic, and hence not needing any such motivation.

Question 2

Did participation have a positive effect on the parents' perception of cooking as a classroom activity?

For the majority of parents the answer to this question would be 'yes'. Reference was made to the relevance of the activity to people's everyday lives. Others spoke of the valuable lessons in co-operation which the pupils could learn from the group work. A number of mothers referred to the value of the activity for their sons. They welcomed the fact that children of both sexes were equally involved in the cleaning up as well as in the cooking.

Two people spoke strongly against this particular activity. One was extremely critical of what she saw as a lack of concern with the nutritional aspects of the activity. Another claimed that it did not fit in with the needs of Grade One pupils. She argued that a physical education program, which allows the children to move about and use up their energy, would be more appropriate than that offered.

Question 3

Did participation have a positive impact on the parents' perception of the teaching profession?

Almost all parents indicated how impressed they were with the teacher's work. Some indicated their appreciation of the time the teacher must have spent outside school hours preparing for the program. Other described the teacher in terms of what were seen as her very positive attributes - her energy, her imagination, her patience, her caring attitude toward the children and her ability to extend the experience of all the children in her class.

A few parents' comments showed that they had used the opportunity to observe some of the skills the teacher had developed, for example one referred to the teachers' ability to keep the lesson moving along.

Question 4

Did the participation of parents have an impact on the program?

A number of parents departed on occasions from the guide sheet to focus the children's attention on other aspects of the cooking activity. For example, one mother who is a nurse by profession, discussed aspects of safety and first aid with her group. Interestingly, in the interview she expressed uncertainty as to whether this was appropriate.

'I teach the cooking with a first aid bias. What do you do if the fat catches fire? Really that's not the right way. It should be emphasizing weights and measures.'

Another parent introduced mathematical concepts not included on the guide sheet. When the pancake mixture was prepared he posed the problem of how to divide the mixture so that everyone got an equal share.

In ways such as these, parents influenced the experienced program. Since the teacher noted some of the parents' ideas, and commented favourably on them, there is every likelihood that the program may be amended in future to include some of the innovations introduced.

Question 5

Where the parents' views of the purpose of the activity congruent with those of the teacher?

One could not say that there was total agreement between the teacher's and the parents' ideas about the purposes of the cooking acitivites.

The teacher suggested that she expected development in six areas as a result of the program. These were (1) in scientific understandings connected with the concept of change; (2) in oral language; (3) in skills such as measuring and timing; (4) in co-operating; (5) in practical cooking skills such as peeling, grating and washing up; and (6) in awareness of safety precautions.

The greatest match between parents and teacher with respect to possible outcomes was in three of these areas. A number of parents indicated that the children would have (1) developed in their ability to co-operate; (2) become more conscious of safety; and (3) learned practical kitchen skills.

The thing that the parents mentioned most often as an outcome of the activity was something the teacher didn't mention - enjoyment. In all probability the idea of providing an activity that is enjoyable for the children is second nature to the teacher and so she did not mention it.

The areas in which the parents either were not really conscious of the possibilities of the activity or were sceptical of achieving development were in the areas of scientific concepts and timing skills.

When asked what the children would get from the activity, only one parent referred to the science orientation of the program and she expressed the view that the scientific understandings were not particularly appropriate to children of that age.

'As far as being a scientific project, I don't think they get much out of it from that angle. Science isn't part and parcel of life, but a good idea as an introduction to life itself.'

With respect to the skill of timing, one parent thought that it was unrealistic to ask the children to time the cooking period. As she put it:

> 'too technical for Grade 1. It said that you should time how long for the pancakes to cook. That was impossible with little people plonking them in and other little people trying to turn theirs over.'

Question 6

What impact did the participation of the parents have on the pupils?

The data show that the parental participation had a significant impact on the pupils. In the grade which did drawings about the cooking activities and were subsequently interviewed, of the 15 children whose parents were involved, 13 drew pictures which related to the lesson in which their parent participated. This would suggest that the presence of the parent was the major impression left with the child.

This study did not generate data which could identify with certainty whether this impact resulted in better attitudes or better learning. It is important, however, to note this result.

All of the children expressed verbal appreciation, during the interview, of the presence of the parents. The majority of them (see Table 1) realized that unless the parents were present they would not be able to participate in the lesson in the way they had. It would appear that most of the pupils had a reasoned basis for appreciating the involvement of the parents, in addition to any affective reaction to the presence of their own parent.

TABLE 1

Response of children when asked why they thought the teacher wanted the parents to participate in the cooking activites

Number of children who said:	
- that without the parents there would be no small group activity	16
- that the parents were present to help them and tell them what to do	6
- they didn't know why the teacher sought parental support	2

The children were asked during the interview what they had learned from the cooking activity. A synthesis of their responses is presented as Table 2. It could be predicted with a fair degree of certainty that without the parental support and hence without the 'hands-on' activity the children would not have responded in the same way.

TABLE 2

Responses of pupils when asked what they had learned from the cooking activites

Number of children who indicated that they:	
- had learned cooking skills	9
- had learned about safety	5
- were not aware of what they had learned	4
- now had a recipe book they could use	4
- had learned how to measure quantities	1
- had learned to co-operate	1

The interviews with the parents gave some other insights into the impact on the pupils. Some parents reported on the enthusiasm of the children for the cooking acitivites. One parent said that her child was able to repeat the cooking task at home without even a copy of the recipe

Teacher's Response to the Data

Our annual cooking program is always a successful and enjoyable component of our total science program. It clearly could not run in the same way without the involvement of parents. It is pleasing to know that many of the parents feel that they are gaining from their participation as well as giving.

I was interested in the response of the parents to cooking as a classroom activity. It would be unreasonable to expect everyone to agree on all aspects of the program and I, and other teachers, will have to continue to live with the fact that some parents may have different views to ours on issues such as nutrition. My policy is to differentiate between "good" foods and foods that we eat on special occasions. These lessons were viewed as special occasions.

It is difficult to know where to draw the line as to the time required, both mine and the parents, to maximise the effectiveness of the participation of parents. As a result of the data collected in 1986 I will devote additional time to make parents more aware of the objectivies of the activity and how these goals can be achieved. Time will be given considering the scientific understandings and skills which I hope will be developed through the cooking activity.

I will again use an evaluation checklist for parents at the end of the program and I will aquaint parents with the results obtained from the use of the children's testsheet.

CONCLUSION

The response of the parents to the request for yet more of their time to take part in the evaluation indicates the commitment of these parents to their involvement in the life of the school. This in itself argues for the effectiveness of their participation. One would hope that the nature of the evaluation in which the evaluator sought to establish not just what they gave to, but also what they gained from, the program would contribute to them feeling valued members of the school community.

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THE IMPACT OF ASSESSMENT CHANGES ON THE SCIENCE CURRICULUM

A DESCRIPTIVE ACCOUNT

Jim Butler and Warren Beasley

INTRODUCTION

> "... how can you possibly award prizes when everyone missed the target?" said Alice.
>
> "Well," said the Queen, "some missed by more than others and we have a fine normal distribution of misses, which means we can forget about the target."

Queensland has instituted a radical new procedure for student assessment that abandons the "fine normal distribution" of grades and which focusses attention directly on the learning goal. This initiative necessitates major adjustments in the traditional pattern of the secondary school. In particular instruction, student assessment and course management will change.

The Queensland system has set the teachers the goal of enhancing the role of formative assessment at the expense of summative assessment. The overall aim is to redirect some of the energy teachers presently give to the task of ranking students towards the goal of educating students.

Formative assessment can be harnessed to learning and course management, while summative assessment is usually coupled to ranking and certification. There will clearly always be a place for summative assessment while schools have the function of ranking students for certification. However, the pedagogical goal set before the Queensland teachers is to exploit the uses of formative assessment and to delay the closure of learning signalled by summative assessment. The aim is to rank and certify students on the "fullest and latest" information about their performance on criteria and standards. The adjustment required of teachers is a radical one and there is no doubt that the journey towards the goal will be both long and fruitful.

In the most common form of summative assessment used in high schools, teachers rely almost exclusively on student responses on paper to tests and assignments. The students is rarely assessed on practical activities, laboratory exercises, contributions and skills in discussion or free expressive exercises (Cohen and Harrison, 1982). What is striking about the student responses to the traditional test items is that they do not reveal the student's thought process that led to the response. Choosing one answer from the five alternatives in a multiple choice item identifies the chosen response but does not reveal HOW the student arrived at it. This is true similarly for single line answers and even for extended problem solving if they only involve algorithmic thinking. The traditional summative test item gathers and rewards only the correct product of a thinking process and not the quality of the process itself.

Formative assessment is the type that reveals the students' thinking processes. It can thus be harnessed to pedagogy and course management. Queensland has set itself the aim of making student assessment an integral part of the teaching/learning process. The space for this development has been created in the certification procedure and the syllabus specifications. The aim of this article is twofold. Firstly, to report on the experiences of Queensland science teachers caught up in this transformation. Secondly, to argue that a strong theme in science education research over the past decade, particularly in New Zealand and Australia, should become an integral part of the movement towards a strong role for formative assessment.

ASSESSMENT AND CERTIFICATION

The requirement that schools award grades and certify student achievement in courses of study means that summative assessment is an integral part of teacher practice.

Grading and certification procedures based on norm-referenced forms of summative assessment are simple to manage and document. The syllabus need only specify the content topics; the teaching can be an uncomplicated progression through the content at a rate that ensures complete coverage of the topics; and the assessment can be designed to occur immediately prior to holidays to keep student attention high. Queensland has had two forms of norm-referenced assessment. From 1911 until 1972 it was done by means of an external exam. From 1973 until 1985 students were assessed by the school and the grades were moderated (Radford et al., 1970). In each case the syllabus was a simple list of topics; but in the era of school based assessment there was a booklet setting out a few assessment techniques.

The awarding of grades in any science subject across the state of Queensland had to approximate a normal distribution across seven grade levels. This form of assessment for grading and certification is what Bates (1984) terms "managerial" because it is for sorting and classifying students. The information such summative assessment provides is not sufficiently rich and comprehensive to help improve learning or teaching.

The ritualization of such a limited form of summative assessment in schools is so pervasive and commonplace that it has become taken for granted by teachers, parents and students. However, the new Queensland form of summative assessment offers a direct challenge to the traditional assessment practices. It replaces the norm-referenced scheme with a criterion-based model under the assumption that standards of performance within the salient dimensions of the science subjects can be identified and described qualitatively. Students are pitted against identifiable standards rather than against each other. This new form of assessment has necessitated major changes. The change to moderated school based assessment in 1972 had little impact on classrooms or assessment procedures. In 1985 there were great changes in the syllabus documents and in assessment procedures. The syllabus under a criterion-based scheme must be formulated in terms of objectives because it is an outcomes-based model (Spady, 1982). The schools are to present students with the opportunity to move through the syllabus with standards of performance being sign-posted by qualitative descriptions of learning outcomes. Such standards and criteria can only by meaningful if related closely to expected learning outcomes. These outcomes constitute the objectives of each topic within a course of study. Queensland has grasped the nettle of "comprehensive" assessment by specifying that these objectives in the syllabus be framed into four categories: content, process, skill and affect. (Scott et al., 1978).

These learning objectives, criteria and standards become the basic operating principle of instructional delivery and student progress. The summative assessment for grading and certification must be designed to gather the "fullest and latest" information on the students in the two years they learn senior science. The criterion-based system also requires that there be a form of time-flexible instruction, flexible student groupings and multiple testing opportunites.

The goal set for the teachers and students in Queensland is to achieve together as high a standard as possible in the two years of senior science. The competitiveness of the individual ethos of the norm-referenced grading system has been abandoned. The criterion-referenced system bestows on assessment the group ethos that is characterises in the instructional setting. These are mighty peaks to climb for the teachers and students. The following section reports on the progress to date.

CURRICULUM CHANGES

The data base for this study was generated as part of a much larger research project which followed the introduction of criteria-based assessment into Queensland secondary schools (Bartlett el al, 1987). Several case studies in a variety of schools were schools used to produce a final report. One of the most important demands made of teachers was to satisfy the requirements of the Board of Secondary School Studies. School work programs specifying objectives, learning settings and an assessment plan were given accreditation following an expert panel review.

This requirement has led to three important changes for teachers:

1. a rethinking of the nature of their subject area as it relates to the perceived educational benefits for students;
2. the specification of objectives under the headings of content, process, skill and affect has encourage the broadening of their teaching goals, and
3. a broadening of teaching strategies as teachers grapple with the requirement to meet a wider range of goals.

Summative assessment plans have been detailed and included in accredited work programs, and the test instruments must now meet design specifications which take account of a range of prespecified objectives.

Student performance on a range of test instruments in now interpreted in terms of standards against nominated criteria. This practice has led to a much fuller reporting of achievement to students, parents and employers. The verbalization of these standards provides some indication of exactly what students awarded each level of schievement are capable of doing.

The administration associated with such a comprehensive system of recording and reporting has proved to be challenging and time consuming. It has led to the generation of profiles of student performance incorporating both quantitative and qualitative descriptions of standards attained.

It is significant that these standards reflect performance at 'exit' from the course of study. Student performance at earlier stages of the course is selectively updated as students mature in developmental aspects of the course.

Although the artifacts of change are visible, viz. new work programs incorporating a broader range of objectives, profiles of student achievement and more informative reporting procedures, it is significant that the teaching/learning settings in science classrooms remain relatively unchanged. The importance of summative assessment procedures and tertiary entrance still cast a long shadow over the potential of school based criteria-referenced assessment. Teachers have cautiously moved into a transitionary phase, but still cling strongly to the idea that quantitative marking schemes which 'count' the number of objectives successfully mastered on a test instrument are safe and efficient.

The criteria for exit performance levels are at this stage more directly related to the number of objectives each student masters in the area of content, process and skill. The difficulty in the identification and use of science related criteria such as knowledge of specific facts, observational skills, experimental execution, and interpretation and explanation, with the associated range of appropriate standards is providing a barrier to learning strategies which incorporate the notion of individual student progression.

Given that the literature which describes the technology for a criteria based system is in its infancy, it is entirely reasonable for teachers to be wary about such a radical change of practice.

ASSESSMENT AND PEDAGOGY

> The quality and effectiveness of instruction are dependent on the quality and effectiveness of assessment. (Spady, 1982).

In many school systems the adoption of an outcomes-based instructional method has run foul of a norm-based grading and certification procedure. In Queensland the reverse is true. The certification process is "achievement-based" and it is the instructional pattern that has to adapt. This fortuitous state of affairs means that the appropriate instruction has been highly developed (Block, 1979). The central feature is a much closer, more frequent but less obtrusive and more direct link between assessment and instruction. This is what Bates (1984) calls the "educational" purpose of assessment; or what other call formative assessment.

According to Block (1979) there are five steps in the instructional process that supports an achievement-based education. These steps are presented with comments derived from the research project (Bartlett et al., 1987)

1.	Diagnosis:	where the objectives attained by the students prior to instruction are ascertained. At present this is perfunctorily done in many classrooms.
2.	Prescription:	where the tasks are designed that will help the students to reach the objectives they do not possess. There is no evidence of this being implemented at present.

3. Orientation: is giving of the target objectives to the students so that more meaning is attached to the learning task. Because the new scheme requires the precise specification of objectives by schools in their work programs, many have taken the opportunity to share them with the students.

4. Feedback: is the conveying of precise information to the students, regarding their progress towards or attainment of objectives. This information needs to be of a form that contributes to a dialogue between the teachers and the student about learning. Teachers in Queensland are experimenting and grappling with this problem.

5. Correction: for the students who have not achieved the objectives, NEW instruction is offered. The temptation here is to think that this step is fulfilled by the customary "revision" period. It is not.

These steps clearly have important implications for instructional management and course design. Teaching must be freed from the tyranny of the "clock, schedule and calendar", and the curricula must be constructed on a core and options model. Both of these freedoms have been allowed in Queensland but the weight of past practice and the hold of the textbook have constrained many teachers. It is clear also that the formative assessment must replace some of the summative assessment procedures; new modes of assessment cannot be introduced and the old retained.

The instructional model presented by Spady (1982) and Block (1979) appears to us to be capable of improvement. A subject master in chemistry had this to say about his response to assessment:

> ... if I found one particular concept which had been examined had been answered badly by everyone, there would be two main inferences I could draw. Either the concept is being presented too early or I didn't teach it very well. (Scarth, 1984).

The worry is that this teacher's inferences and the "correction" step of Block are based on the classical empiricist doctrine or the so called "blank-slate" model. It seems to us, particularly as science teachers, that such a model is erroneous.

The results of much science education research clearly demonstrate that students approach learning with a set of prior conceptions. The 'conceptual change' viewpoint has replaced the "blank-slate" model (Posner, 1982). It is in this regard that the generative learning model of Osborne and Freyberg (1985) can be used to make the Block (1979) model more powerful. The need for change is exemplified in the work of McCloskey et al. (1983):

> "... not only do pre-instructional concepts persist into the learner's tertiary learning experiences but also that students often prefer them to the correct scientific concepts."

The changes indicated by the conceptual change epistemology to the instructional process of Block (1979) are as follow:

1.	Diagnosis	will reveal the students' prior conceptions. Fortunately the research indicates that they are limited to a small number.
2.	Prescription	will design tasks and activites that challenge these prior conceptions and attract students to the curriculum objectives.
3.	Orientation	will state the objectives that encompass the scientist's view of the topic.
4.	Feedback	both about the inadequacies of the student's prior conception and the power of the scientist's conception.
5.	Correction	a new strategy to challenge the prior conception or support the scientist's conception.

For science teaching at least, in Queensland there is a clear conguence between a significant trend in science education research and the new achievement-based form of education. The task is to implement the instructional model in the classroom.

CONCLUSION

Queensland has adopted an achievement-based system of certification and instruction. Put simply, the traditional assumptions that the capacity to learn can be demonstrated by measuring the speed of learning, and that knowledge can be simply transferred from the teacher or the textbook to the student - have been deliberately dropped. This has created a home for the science education research dealing with the significance of prior concepts in science teaching. The teachers are on the move towards the goal.

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SCIENCE CURRICULUM DEVELOPMENT IN NEW ZEALAND

A HISTORICAL ACCOUNT

Beverly Bell

INTRODUCTION

There have been three main influences on curriculum decision making in science education in New Zealand in recent decades. The first was the influence of the logical structure of science. The 'big ideas' and concepts such as energy, matter, and evolution were used as a framework for structuring the curriculum over the years of a child's formal science education. The New Zealand 1968 junior science syllabus was a product of this international trend.

The second influence was what we know about how people learn. Concerns began to be expressed in the mid-1970's about the mismatch between the logical structure of science and the way children learn science, for example with the teaching of the particulate nature of matter with 11-13 year old students. In New Zealand, this concern resulted in the setting up of the first Learning in Science Project, which had the initial (but not the final brief) of researching what would be appropriate to include in the curriculum at each level. Since then, the three Learning in Science Projects (LISP, LISP primary, LISP energy) have contributed much to science curriculum research and development in New Zealand. In particular, they have forced us to consider the learner's ideas and skills which she or he brings to the learning task, the way these ideas influence the learning process and outcomes, and different teaching and learning activities. Hence, the significant contribution of the Learning in Science Projects was, and still is, to highlight the role of learning theory in curriculum decision making.

A third and growing influence on curriculum decision making in New Zealand is the important social concerns of race and gender equity and consultation, which the recent Ministerial Curriculum Review has highlighted.

THE CURRICULUM REVIEW

In November 1984, the Minister of Education set up a committee to review the curriculum for schools, with wide public consultation. The committee was concerned to get the views of as many people as possible, including those who are not normally involved in educational policy making, for example, those who have not been successful at schoolwork, those who did not enjoy school, Maori and Pacific Islands communities, community and adult education organisers, parents of students and the students themselves.

To help people start discussing and writing submissions, seven discussion papers were written and disseminated, titled:

1. What do you expect of our schools?
2. What should young people learn and experience in schools?
3. How should schools reflect the many cultures in New Zealand?
4. How should all people be given a fair chance in our schools?
5. How should people in schools and the community work together?
6. How should schools be organised to help people learn?
7. Assessment and awards in the senior school?

Each booklet contained a pull-out self-addressed response sheet that could be easily filled in and posted to the committee. Booklets 3 and 7 and the general information pamphlet "Look at Learning in Schools" were written in Maori and English.

The Minister of Education also wrote an open letter to students to encourage them to contribute to the review.

The booklets were released over a period of four months in the hope that discussion would continue over a longer period and seven months were given for people to make their responses. On the whole the media co-operated with radio, television, newspaper, and a magazine publicity and articles. Other help was given, for example, the McDonalds groups printed special placemats for their use in restaurants, giving information about the review.

A total of 21,500 responses were received by the deadline date of 31 January 1986, when a draft report was written, not as a simple poll or detailed collection of statistics, but as a summary of the range of opinions on a wide variety of issues. The committee documented issue by issue what respondents had said. This draft report was sent to all respondents to the discussion booklets and others, and 3 months were given for public debate and response to the draft. A final report was then written.

This final report of the Committee to Review the Curriculum for Schools, The Curriculum Review, is notable on several accounts:

1. It is the first major education report that promotes the ideas of a non-racist and non-sexist curriculum for all New Zealand students.

2. It is the first major education report that promotes the recognition of the Maori people as the tangata whenua (people of the land).

3. It acknowledges the place of the learner at the centre of schooling and the curriculum. The curriculum must be seen by the learner as whole, enabling, useful, and enjoyable.

4. It has used the wider definition of 'curriculum', that is "all the activities, events, and experiences that take place in the school's learning programme".

5. The responses indicated that the community wanted to be involved in curriculum development at the school level. The report promotes a move from national to school based development work, within a national framework. It suggests the setting up of local Curriculum Planning Groups made up of students, teachers, administrators, parents and others from the community, to manage the process of consulting, of planning, of evaluating, and of reviewing the school's curriculum design, and for reporting regularly to the managing body.

The report states:

> "The community responses by the Committee indicate that the first task for schools is to make sure that students:
>
> * acquire the basic skills and knowledge that enable them to go on learning;
> * develop the skills, knowledge, and attitudes needed to function effectively in everyday life, now and in the future;
> * develop respect for themselves and for others, and the skills needed to live and work with other people."

A second message to emerge from the public response is the need for all schools to promote a sense of cultural identity and tradition for all New Zealanders. Many also wish for recognition of the tangata whenua, with a commitment to the aspirations of the people belonging to all cultures who make up New Zealand society.

A third expression of public opinion is that the curriculum for any particular school should be developed through consultation between the school and the community, but should be based upon national guidelines.

The report is also notable for the following:

- "there will be a national common curriculum for all schools, from new entrants (age 5) to Form 5 (age 15-16).
- the national common curriculum provides for a broad and general education and consists of:
  a) national curriculum principles
  b) three inter-related aspects of learning: knowledge, skills and attitudes and values"

The list of principles and aspects of learning are given in Appendices 1 and 2.

The subject of science is not mentioned explicitly but the knowledge part is incorporated into the aspect of learning about the understanding of the biological, physical, and technological worlds. However in a wish to integrate the learning into a whole from the students', not teachers', point of view, it is included with social science and physical geography aspects (and how people interact with and influence their environment).

Many of these fifteen principles are an expression of the social influences on curriculum decision making, for example, the curriculum shall be accessible, non-racist, non-sexist, responsive, and co-operatively designed, while others are based on how children learn, for example, the curriculum shall be whole, reflect the fact that education is a continuous and life-long process, inclusive, enabling, help children achieve success and be enjoyable. Others reflect a growing accountability movement, for example the curriculum shall be of the highest quality, planned, and common to all schools. These principles can act as guidelines and a checklist for the local curriculum planning groups.

A Curriculum Review Action Unit of four people, has been established by the Department of Education to co-ordinate the department's response to the Curriculum Review. Initially, its task is to identify the issues which require immediate action, for example, to design a model for clarifying (and responding to) the needs of teachers, parents, students, groups and individual communities in their responding to the broad aims of the Curriculum Review report. One kind of support being considered is a network of project teams working in consultation with organisations represented by the Curriculum Review Committee, other interested parties, and review schools to develop draft materials for the review schools and their communities to use and evaluate, on such topics as improving teaching and learning, promoting gender equity, promoting Maori language and culture, encouraging wider community participation, and developing a National Curriculum statement.

THE FORM 1-5 SCIENCE REVIEW

Parallel to this ministerial review of the whole school curriculum, has been the review of science education (11-15 years). This is the first significant opportunity to change the science curriculum in the light of the learning theory and social concerns of the 1970's and 1980's. These mirror the concerns expressed by the wider New Zealand community in response to the discussion papers of the Ministerial Review. They include:

a. developing teaching and learning activites to help students construct understandings about their biological, physical, and technological worlds that are meaningful and useful for them. The research work of the Learning in Science Projects (Osborne and Freyberg, 1984; Osborne and Biddulph, 1984; and Carr et al, 1986) and of the Science Education Research Unit on generative and interactive teaching and learning models is a rich base upon which to begin development work;

b. developing teaching and learning activities and curriculum materials that help more students feel a part of a sense of belonging to science, by using the experiences, interests, and concerns of girls, Maori and Polynesian students in the classroom as well as those boys, (Bell, in press);

c. developing a science curriculum that promotes a view of science as a human activity (Bell, 1986a); and

d. a curriculum that encourages students to keep on asking questions about their world and to help them seek answers to those questions, hence helping students to be more responsible for their own learning.

A consultative committee (the Form 1-5 Review Committee) was convened to guide the review and, unlike previous ones, has representatives from many organisations concerned with science education.

At its initial meetings, the committee was concerned to involve as many teachers, and others interested in science education, as possible, and a professional development model of curriculum development was chosen. This model takes into account that curriculum development is not just changing the printed syllabus (the official curriculum) but about changing science educators' ideas (the teachers' intended curriculum) and behaviour (the teachers' actual curriculum) so that the important curriculum (the students' perceived curriculum) is also changed. Curriculum development is about helping educators to change their ideas and behaviour, and therefore about conceptual change and professional development. It is based on what we have learnt about conceptual change in science education and a constructivist view of lerning (Bell, 1986b). To-date, two main activities have attempted, within financial constraints, to put this model into operation. Firstly, eight discussion papers on key issues in science education, were sent to all schools:

- learning in science
- girls and science
- science and technology
- aims of science education
- the role of practical work
- assessment
- linkage between primary and secondary science
- multicultural/bicultural science

The purpose of these papers was two-fold: to clarify for the science review committee the current ideas and opinions of those involved and concerned about science education, and to begin the debate and discussion that is an integral part of the learning (conceptual change) process. This second purpose will be continued with the publication of newsletters summarising the responses to each of the discussion papers. Other discussion papers are being produced as the need arises, for example the recent paper on the use of computers in science education. The second main activity to implement a professional development model of curriculum development was the setting up of the eight development groups. Traditionally in New Zealand, a new science syllabus was written by a review committee over one or two weeks of national conference time and then disseminated to schools for comments. This time, it was proposed that eight groups of teachers and support people will contribute along with the current review committee to the ideas, debate, and writing of the new syllabus statement (or guidelines to accompany the relevant aspect of learning in the National Common Curriculum) over 2-3 years. To set up the groups, an advertisement was placed in the national Education Gazette to invite teachers and others to submit proposals for development work. The tasks for the groups are to:

- act as a resource group on a particular issue for the committee,
- develop, trial and evaluate curriculum materials, for example, inservice kits, teacher guides, and
- assist where appropriate in the writing of the new F1-5 science curriculum statements.

Inviting proposals from interested people is new in science curriculum development in New Zealand and is an attempt to combine the periphery-to-centre-to-periphery model of the British Secondary Science Curriculum Review with the existing mode of national curriculum funding in New Zealand.

Twenty submissions were received and the eight selected were:

- bicultural science (Auckland)
- science, technology and society (Rotorua)
- girls and science (Napier)
- linkage and Form 1-2 science (Taranaki)
- planning a local science curriculum (Kapiti Coast)
- LISP teaching and learning approaches (Wellington)
- teaching and learning strategies in science (Christchurch)
- practical work, problem solving (Dunedin)

The aspects to be researched and developed reflect the influences on curriculum decisions of learning theory and social concerns. Some of the groups will be looking at learning issues (practical work, learning and teaching strategies), others at social concerns (girls and science, bicultural science, planning a science curriculum, linkage and consultation). The science and technology group is attempting to up-date the science curriculum by the inclusion of technological aspects, as well as indicating the links with other areas of learning and different teaching approaches.

It is hoped that, like the teachers involved in the SSCR working groups, the eighty or so teachers involved in developing the new science curriculum will develop further their ideas, for example, on learning and teaching approaches, and act as catalysts for other teachers move professionally also.

SCIENCE FOR ALL

Both the intial prosposals of the science review and those of the ministerial review are recommending changes that are supportive of the 'science for all' moves in science education. For example, in the report 'Curriculum Review' the fifteen principles advocate learning, including learning in science, that is useful, relevant, enabling, accessible, enjoyable, successful, and integrated for all students, including:

- girls as well as boys
- Maori, Polynesian as well as European students,
- those seeking and not seeking future employment in science and technology,
- all students in Form 5 (age 15)
- students with different experiences and aspirations
- students with different abilities and skills
- students with disabilities, for example, blind students

The eighth principle addresses the notion of a 'balanced' curriculum and in terms of the science curriculum, this may be balanced with respect to:

- the different branches of science, e.g. earth science, biology, physical science
- knowledge and skills
- the other aspects of learning, e.g. language
- a student's point of view, e.g. to balance learning outside school in hobbies
- individual and national needs for prerequisite employment skills and qualifications
- different teaching, learning, and assessment modes, and
- over the current school year and/or the total education for the student from 5-15 years.

The teachers and others involved in developing a new science curriculum have the support of a major educational review to work towards a science education that is sensible, relevant and useful for all students, not just for the few who will maintain the elitist science (Fensham, 1987).

SCIENCE EDUCATION RESEARCH

The Department of Education is currently funding research in three areas:

1. The Learning in Science Project (energy) continues to explore learning, especially conceptual change in the learning of 'energy' and in teacher education.

2. The University Students as Secondary School Tutors Project of the Higher Education Research Unit at the University of Auckland, is investigating the use of university science students (in particular women and Maori and Polynesian students) to act as tutors in secondary science classrooms. Modelled on a similar project in London (Goodlad et al, 1979) it is hoped the interaction of the two groups, will encourage the university students to take up a career in science education (New Zealand like many other countries has a shortage of science teachers) and that the university students (girls and Polynesians) who do not usually continue with science education at the senior secondary and tertiary level.

3. The eight development groups for the Form 1-5 science review have all indicated in their submissions on proposed development work an element of research, including clarifying the current situation in the local areas with respect to the issue concerned and action-research as part of the development cycle.

Hence, the research as well as the development work is reflecting two main influences on the curriculum - how people learn, and the social concerns of equity and consultation, including school-based development work.

SUMMARY

Science education in New Zealand continues to have a strong research base and now development work has begun that is modelled on a view of how people learn and which is supported by the curriculum development of the wider Ministerial Review.

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Editorial comment:

Members of the Australian Science Education Research Association are well aware of many initiatives being taken by teachers in schools to improve the quality of science education and to increase the rate of participation of girls in science courses. ASERA has encouraged teachers to come to the annual conference to tell the researchers about initiatives being taken. For the benefit of RISE readers we have included here one account of science teachers' initiatives presented to the ASERA annual conference.

"GIRLS ONLY" SCIENCE CLASSES AT SCORESBY HIGH SCHOOL

Sylvia Wood and Jacqui Franck

In early 1986 a statistical analysis of the enrolment figures in senior science classes (Years 11 and 12) at Scoresby High School indicated that a disproportionately low number of girls were studying the physical sciences, and that girls were under-represented in senior classes as a whole (see Table 1).

The science staff, in particular, were aware of the debate about girls' participation and success in science, mathematics and techological subjects or careers. What could be done at the school?

THE SITUATION

Scoresby High School is a government high school located in the outer eastern suburbs of Melbourne, Victoria. There were 950 students (389 male and 568 female) with a staff of 80 in 1987.

The school curriculum, discipline and social structures can be described as traditional. Students are expected to wear a uniform, to be prompt to class and polite to other people. Honesty and a respect for the rights of others is also policy. The curriculum offered at Years 11 and 12 is of an academic nature and is based on the Victorian Curriculum and Assessment Board's (VCAB) externally assessed Group 1 subjects.

TABLE 1

MALE/FEMALE STUDENT NUMBERS IN SENIOR SCIENCE CLASSES AT SCORESBY HIGH SCHOOL 1986/87

1986			1987			
SUBJECT	YEAR	MALE	FEMALE	YEAR	MALE	FEMALE
PHYSICS	11	14	8	11	9	16
12	14	5	12	6	4	
CHEMISTRY	11	11	6	11	8	18
12	8	2	12	2	5	
BIOLOGY	11	4	17	11	14	22
12	4	17	12	5	16	
GENERAL SCIENCE	11	19	8	11	19	12

The science Department offers science as a compulsory core subject to all Year 7 to 10 students. It also offers extra science as an elective for Year 10 students.

The male/female ratio of science teachers in 5:6 with four of the female teachers taking senior science classes of chemistry and biology.

The pilot project reported in this paper was conceived by the Science staff at Scoresby High School during 1986. It is hoped that this report of how the "girls only" classes were established within a regular school setting may prompt other schools to address the issues of girls in science.

WHY "GIRLS ONLY"?

After a number of informed discussions at the school with science staff and teachers from other curriculum areas the decision was that the goals that were desirable and achievable included:

- increasing the girls' participation in senior science and in the senior physical sciences in particular;
- broadening the career opportunities of girls by encouraging a greater participation in the sciences;

- attempting to change the attitudes of girls towards the sciences as subjects to be studied at school;
- fostering the confidence of girls in their ability to be successful in science subjects;
- increasing teacher, student and parent awareness of the obstacles facing girls wishing to study sciences.

A literature search to see how others had attempted to solve the problems of discrimination against girls in science classes presented three possibilities, namely:

i) attempt to alter the teaching practices of the teachers to take into account specific problems faced by girls in mixed science classes, i.e. teacher awareness of adverse classroom dynamics;

ii radically changing the current science curriculum, i.e., sexually inclusive curriculum;

iii) trial "girls only" classes and research the effect this would have on the girls' achievement and participation. If this proved successful consideration would be given to committing all science classes to the scheme.

The disadvantages and advantages of each of these alternative strategies were discussed by the science staff before it was decided upon the "girls only" approach.

A change in curriculum would need to be extensive (from Years 7 to 10) and it was perceived that changing curricula at Years 9 and 10 for girls only may be viewed as a "soft option".

Altering teaching practice by making teachers more aware of classroom dynamics does not necessarily change teacher attitude and expectations. It is also difficult to change entrenched teaching strategies.

Another reason why the third approach suited this school was because the female/male ratio within the school as shown in high. Therefore no "all boys" classes were created. This also caused minimal disruption to school structure, administration and staff.

THE PROCESS

Once the Science Faculty had decided that the approach of "girls only" science classes at Years 9 and 10 for two years was feasible the processes of gaining support from the school and the school community were commenced. Table 2 gives an indication of the steps undertaken to implement the pilot project of "girls only" classes at Years 9 and 10 for 1987/88.

TABLE 2
THE PROCESS OF IMPLEMENTATION 1986

1. Informal discussion between proposers.
2. Research of available data.
3. Inform appropriate committees, i.e., science staff initially.
4. Organise publicity material within the school community and the wider media.
5. It was proposed that the girls' classes would run in Years 9 and 10 with two all girls' classes in each.
6. Time line of requirements
7. Submission to curriculum committee. (March 1986)
8. School co-ordinatore ratified the fact that the proposal could be time-tabled.
9. Report back to Curriculum Committee, approval was granted and referred to Education sub-committee (school council).
10. Presentation to Education sub-committee.
11. Presentation to School Council.
12. Publicity to school and local community, including a "Careers Information Evening" for parents.
13. Evaluation - it was considered appropriate to seek outside assistance with the evaluation of the project.
14. Promotion of science to girls when selecting subjects for the following year.
15. Selection of girls into classes:
    i) student volunteers
    ii) parents volunteer students
    iii) teachers select suitable students by consultation with other teachers and students where possible.
16. Balancing of mixed classes so that student male/female ratios would be relatively even.
17. Staff selection to take "girls only" classes. Staff were asked if they were willing to take these classes.

Several aspects of the implementation process demand further explanation.

Firstly the publicity of the project both within the school and its community as well as the broader local community was a considered decision as well as the broader local community was a considered decision of the school in an attempt to ensure that what was being attempted at the school, although unusual, was not reactionary or revoluntionary. In fact the school might gain from the whol project. Articles were produced for the local newspaper, school newsletter, Maroondah Equal Opportunity Centre, Ms Muffett and the Victorian Secondary Teachers' Association. The science co-ordinator and teachers also promoted science generally within the school.

Secondly, without proper evaluation the results of the project would not be valid. The school was also mindful that teachers do not have the time nor expertise to properly evaluate such a project. The organisations approached to carry out the evaluation were:

i) McClintock Collective

ii) Schools Commission

iii) Curriculum Branch of the Ministry of Education (Research and Development)

iv) Participation and Equity Program within the Ministry of Education

v) Monash University Education Faculty. (Approached Schools Commission for projects of National Significance - this unfortunately was rejected). Monash University Faculty was the only group willing to commit themselves and take responsibility for the evaluation of the project. The school was specific about when the evaluation should be carried out, the content of surveys used and the type of information to be gathered. (Schools are also constrained by the type of surveys which can be given to students.)

PROBLEMS

This project is not a research project established by a researcher from a higher education institution. It more appropriately should be seen as "Action Research" or "Teachers as Researchers". Consequently, the vagaries of the day life of a school have affected the project in a number of ways. Table 3 gives an outline of the main problems.

TABLE 3
PROBLEMS OF IMPLEMENTATION

---

1. 1986 Science co-ordinator took long service leave early in 1987 and was transferred to another school.
2. Insufficient girls volunteering for girls only class.
3. One Year 10 Home group disbanded due to staffing problems.
4. Selection of teachers for girls only classes.
5. Time-tabling constraints - was overcome relatively easily by grouping four classes of science together.
6. Staff changes during the year.
7. Publicity of the project during 1987.
8. Unexpected outcomes.
9. Selling the project for 1988.

Several of these problems, in hind-sight, could have been anticipated, however in the hurly burly of the day to day activities of a school things to get overlooked. For instance, the staffing of the "girls only" classes was two female teachers at Year 9 and two male teachers at Year 10. It would have been preferable to have had one male/one female teacher at each level.

The disbanding of one of the Year 10 Home groups means that several girls were forced into the "girls only" science groups.

The publicity that the project has drawn has unfortunately made several classes of "girls only" science "feel" very different, because they are the group that have been photographed and talked to. This of course was not the aim of the school.

Finally, a comment should be made about one of the unexpected outcomes of the project, and that is, staffing of excursions. There are two unfortunate, but not insurmountable problems for excursions:

1. When the Home group goes on an excursion teachers are not necessarily released; and
2. a male teacher of the "girls only" class must be accompanied by a female teacher.

CONCLUSION

At present the evaluation team is about to collect information following the first 4 - 6 months of the projct, so there is very little to report from this point of view. However, as a school-based attempt to offset the discrimination of girls in science, the project is progressing with very little interference from and to the school. It is hoped that there will be some concrete changes in subject and career choices, as well as attitudes toward science by the girls in the project due to the efforts of the science staff.

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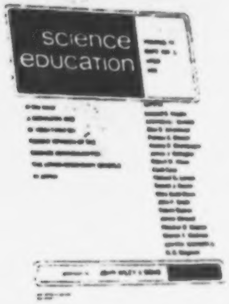

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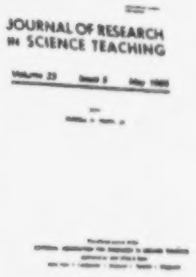

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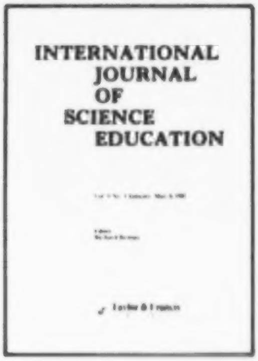

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